CLIENT	**BENGALURU SMART INFRASTRUCTURE LIMITED (B-SMILE)** #108,1st Floor, Annexe-2 Building N.R. Square, Bangalore
PROJECT	Consultancy Services for Preparation of Detailed Project Report for Proposed Construction of **Elevated Corridors from Minerva Circle to Hudson Circle and loop flyover from existing Bala Gangadhara Nath Swamiji flyover to Townhall and Elevated Corridors from Sangolli Rayanna circle (Anand Rao Flyover) to Nrupathung road (KR Circle).**
Title:	**DETAILED PROJECT REPORT (VOLUME-1)**
Doc No.	Report No. VAX/JCR/DPR/01

DPR CONSULTANTS	**Vax Consultants Pvt. Ltd.,** **Foundation & Structural Engineers** **No 18, Gangai Amman Koil 4th Steet, Vadapalani** **Chennai - 600026**

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CHAPTER -1 – INTRODUCTION

1.1 Back Ground.

Bangalore is one of the metropolitan cities in India and situated in the Southern part of the Karnataka state. The total extent of Bangalore metropolitan area (BMA) is 8005 Sq. km of which the main city compresses an area of about 741 Sq.km, the total population of Bengaluru is about 140.00 lakhs. Bangalore is located southern India 12°59'N 77°35'E longitude. Bangalore is "Silicon Valley of India" (or "IT capital of India") because of its role as the nation's leading information technology (IT) exporter A demographically diverse city, Bangalore is the second fastest-growing major metropolis in India.[20] Bengaluru has one of the most highly educated workforces in the world.[21] It is home to many educational and research institutions in India, such as Indian Institute of Science (IISc), Indian Institute of Management (Bangalore) (IIMB), International Institute of Information Technology, Bangalore (IIITB), National Institute of Fashion Technology, Bangalore, National Institute of Design, Bangalore (NID R&D Campus), National Law School of India University (NLSIU) and National Institute of Mental Health and Neurosciences (NIMHANS). Numerous state-owned aerospace and defence organizations, such as Bharat Electronics, Hindustan Aeronautics and National Aerospace Laboratories are located in the city, with its own well developed industries. The steady acceleration into the fast lanes of industrialization has come up rapidly.

Bangalore is rated to be one of the fastest growing cities in Asia. During the last couple of decades, the life style of people and their commuting habits have undergone radical changes due to steep hike in the cost of urban land

in Bangalore and the revolutionary changes in Automobile, Information Technology and Bio Technology Industries.

During this period the movement of people, from rural Karnataka and rest of the country, to Bangalore has also increased considerably due to reasons such as:

- Better industrial climate in Bangalore
- Better employment opportunities
- Growth of other industries due to growth in IT sector

The prime drive of an urban economy is the Urban Transport infrastructure, facilities and services. Trade, industries and other economic activities thrive in areas where accessibility is good and mobility fast and smooth. Urban development takes place around such activity generators. Transportation is playing a vital role in the economic growth of the cities. It is able to make a substantial contribution to city efficiency when men and materials are transported at minimal investment and operating costs. Thus, an able, adequate and efficient transport system enables cities to become catalysts for economic, social and administrative development.

In view of the above, there has been a steep increase in volume of vehicles on the city roads. The lack of need-based public transport system and the absence of any mass rapid transport system to commensurate with the development and increased vehicle population have further aggravated the problem. This is seriously being felt at the intersections and consequently the intra-city commuting time has increased substantially, in addition to accidents and pollution levels. Hence, there is an urgent necessity to decongest the over congested intersections.

1.2 Need for the Project:

B- SMILE, Bengaluru Smart Infrastructure Limited, a Special Purpose Vehicle **(SPV)** created by Karnataka government, **B- SMILE** responsible to oversee and implement major projects in Bengaluru. As a comprehensive solution for **End to End traffic solution** to the city of Bangalore the **B- SMILE** is planning for 120 km of elevated roads in the various part of the city to provide End to end solutions.

The project under consideration is –

Construction of Elevated Corridors from Minverva Circle to Hudson Circle and loop flyover from existing Bala Gangadhara Nath Swamiji flyover to Townhall and Elevated Corridors from Sangolli Rayanna circle (Anand Rao Flyover) to Nrupathung road (KR Circle).

Main objective of the above project is to connect the traffic from South Bangalore side moving towards North / City Centre side. The location being central part of the city, traffic flow in this corridor is from southern Part of Bangalore towards SJP Road, Kempegowda Road, Magestic, Vidhana Soudha & M.G Road. Also, the Present traffic flow pattern from other direction, i.e., traffic from KR Circle, Sheshadri Road, Race Course Road, Vidhanasoudha is such that, it has to go via Lalbagh to reach southern parts i.e., Jayanagar, Basavangudi, Banashankari JP Nagar etc. Attempt has been made to bring the traffic directly on Elevated corridor on JC road integrating with flyover from Sheshadri Road, leading the same to RV Road thereby minimising the travel time and avoiding the traffic signals. Also, with one arm connecting existing BGS fly over which starts from Mysore circle will directly

leave the traffic to the various roads, KG Road, Kastur ba Road using the elevated rotary, proposed at Hudson circle. The Fly over connects the Tunnel Road, towards Hebbal being planned by Government of Karnataka which is a vital link for vehicles going towards Hebbal.

The main junctions along this corridor are- Minerva Junction, Bharath Talkies Junction, Shivaji Talkies Junction, Town Hall Junction, LIC (Badami House Junction), Ulsoor Gate Police Station, KG Road, Nrupatunga Road, Rajaram Mohan Roy Road, KR Circle, Freedom Park Junction, SJP Road.

The travel speed of the vehicles throughout the day is 15-20 kmph with frequent jams. The waiting time and queuing of vehicles during peak hours is high at these junctions. Presently it requires about 25 to 30 minutes to travel between 2 nodal points (i.e., Minerva circle to Hudson Circle). Pedestrian volume is also considerable in the area because of commercial activities on the factors it is necessary to provide "**Elevated Corridor" from Minerva Junction to Hudson Circle Junction integrating with flyover from Anand Rao Circle to Nrupatunga Road Via KR Circle, connecting flyover to Bala Gangadhara Swamy Flyover to JC Road at Bangalore** which carries through traffic, thereby reducing the delay in travelling time, reduction of surface level traffic etc.,

To arrive at better picture about the present situation following studies are conducted –

- Topographical Survey
- Geo Technical Investigations.

This report presents above studies, detailed specifications, Bill of quantities, estimates and recommendations to decongest the surface level traffic and improved travelling conditions for traffic along JC Road, SJP Road, Sheshadri Road connected roads.

Chapter – 2 – OBJECTIVE AND SCOPE OF STUDY

2.1. Objective

The tender for Detailed Project Report for Construction of Elevated Corridor from Hudson Circle to Minerva Circle awarded by **M/s. BBMP to M/s. Vax Consultants Pvt Ltd.,** through competitive bidding.

As per tender condition, Detailed Project Report was Submitted after review of TAC.

Further work is taken up by **B-SMILE,** in-view of comprehensive solution for **End to End traffic solution** with following additional Scope of Work –

a) **To revise the span arrangements and super structure with lesser dead load for Proposed Elevated Corridor from Hudson Circle to Minerva Circle.**
b) **Additional flyover from Anand Rao Circle to Nrupatunga Road Via KR Circle.**
c) **Proposed flyover from Bala Gangadhara Swamy (BGS) Flyover to JC Road flyover for traffic from Mysore road.**

2.2. Project Scope:

The scope of the consultancy study involves the following -

1. Review of available data and reports
2. To conduct necessary additional Topo Survey.
3. To prepare Concept Drawing and integrate with the elevated corridor of Minerva circle to Hudson circle.
4. To prepare alignment option Drawing and typical cross sections, longitudinal section.

5. To prepare General Arrangement drawing for approved alignment for the corridor.
6. To Conduct Additional Geo-Technical Investigations.
7. To Study of "Structural System" revising super structure with UHPFRC and its Evaluation.
8. Liaisoning with stake holders / department for identification of their utilities, assets and mapping of utility along corridor.
9. To Prepare of preliminary designs for the structures of elevated corridor.
10. Preparation of Land Acquisition Plan and Schedule and Assisting B-SMILE for Preparation of Form-1 notification for TDR.
11. Preparation of Draft DPR.
12. Preparation of Final DPR on approval of Draft DPR.
13. Preparation of Tender documents and assist for tender process.
14. Co-ordinating with various agencies involved in easing traffic in the city and suburban area of Bangalore City such as, Elevated Corridor, Metro Rail Project and their extension up to and into the Junctions under study will also be studied and factored-in while finalizing the proposals.

2.3. Approach Methodology:

2.3.1. Stage - I Field Investigation:

- Review the available Data.
- Conducting additional Topo Survey.
- Identifying the utilities.

2.3.2 Stage - II Analysis and Design required for preparation of necessary drawings for EPC Contract

- Preparation of Alignment Drawing and discussing with the authorities for approval of the same.
- Preparation of General Arrangement Drawing and discussing with the authorities for approval of the same.
- Analysis of typical Super Structure with UHPFRC material and typical sub structures.
- Preparation of Typical cross sections of Super structure and sub structure for tender purpose
- Environmental impact analysis.
- Preparation of detailed BOQ and cost estimates along with rate analysis.
- Preparation of Tender documents.

2.4 Design Philosophy.

The Technical proposal given in this Report consists of Designs, Drawings and all Technical Details based on Surveys and Investigations stated in Section 2.2 above. The Design standards adopted in the present Design are in accordance with the codal provisions of India as stipulated by the Indian

Roads Congress (IRC), Indian Standards Specification (IS) and the Ministry of Road Transport & Highways. Deviations may be considered in planning parameters if extremely necessary considering the dense urban conditions, like the present one, from the present codal provisions. These modifications in the design will be adopted based any recognised international codes, such as Euro code, BS codes, ACI, DIN, French codes and/or on similar projects at urban locations as "Good Engineering Practice".

The Designs and Drawings presented as a part of this report are based on the Studies, Investigations and Designs which provide a fair basis for making Detailed Designs and Drawings subsequently. The consultants opine that the detailed engineering designs and drawings shall be prepared on the basis of this report before construction, based on actual details at site viz., utilities, Geo Technical data and Soil profile etc. by the project implementing agency.

2.5 Deliverables:

Following are proposed to be submitted as part of the Detailed Project Report -

a) Main report

- Executive summary
- Introduction
- Traffic surveys including traffic forecast.
- Engineering surveys and investigations and proposed road features
- Design standards and specifications
- Drainage facilities including cross drainage structures

- Environmental and social issues / considerations and proposed rehabilitation and resettlement measures
- Material, labour and equipment
- Typical design details of various components.
- Rates and cost estimates inclusive of land acquisition cost.
- Construction program and constraints.
- Traffic management and safety measures during construction.
- Shifting of utility lines and cost.
- Plan of action for Traffic diversion and roll of Traffic police.
- Miscellaneous.
- Conclusions and recommendations.
- The design calculations etc,

b) Cost Estimate

c) Drawings

d) Tender Document

Chapter – 3 – PROJECT COSTING

3.1. General

The project cost has been estimated mainly based on the rates derived after rate analysis using Schedule of Rates of Uni SR 2023-24 Karnataka Public Works Department, supplemented by issue price list issued by the Superintending Engineer PWD (Bangalore Circle) issue date 08.10.2025. For the few items not covered in the above SR, rates from NH SR / market rates have been adopted. The Data rate for UHPFRC, which is not in SR has been workout and presented in Annexure below.

The detailed estimate is enclosed as Appendix -1. At the end of the report. The COST SUMMARY for the project is shown in below and following are considered–

- **Proposed Flyover Elevated Corridor from Hudson Circle to Minerva Circle with elevated rotary at Hudson circle.**
- **Proposed flyover from Anand Rao Circle to Nrupatunga Road Via KR Circle.**
- **Proposed flyover from Bala Gangadhara Swamy (BGS) Flyover to JC Road flyover.**
- **Lumpsum provision for At grade Junction improvement at Lalbagh west gate and RV road from touch down point to the Lal bagh junction**

3.2. COST SUMMARY

Sl. No.	Items	Amount (In Rs)
1	Site clearance and dismantling	994,048.00
2	Compound wall construction	11,263,295.00
3	Flyover works (via duct portion)	4,992,467,970.00
4	Flyover approach works	132,795,340.00
5	Diversion road (maintenance work during construction)	13,249,210.00
6	Drain/footpath	11,003,689.00
7	Surface level road /slip roads (post construction)	58,522,614.00
8	Road furniture & other work	13,058,308.00
9	Overhead gantry	7,558,566.00
10	Pier protection below flyover	33,116,451.00
11	Electrical works	51,403,770.00
12	Preliminary works and Design Charges	45,472,167.00
		5,370,905,428.00
	GST @ 18%	966,762,977.04
	Total Civil Cost, Rs.	**6,337,668,405.04**
i	Provision for Contingencies and Provision for Departmental Establishment Charges @ 2% on APT	107,418,108.56
ii	Provision for Independent Engineer / PMC @ 1.50% on APT (Including GST)	80,563,581.42
iii	Provision for Price escalation @ 2.5% for the 2nd year i.e., 0.5% of APT (Including GST)	134,272,635.70
iv	Provision or utility shifting @ 8% of Project cost (APT) (Including GST)	429,672,434.24
v	Provision for Arboriculture/ Afforestation @ 0.50% on APT (Including GST)	26,854,527.14
vi	Land Acquisition Cost including Structures	65,635,200.00
vii	Provision for Lalbagh west gate at Grade improvement	50,000,000.00
viii	Miscellenous and other Department Deposits	17,915,109.23
	Total Project Cost	**7,250,000,00.00**

Rupees Seven Hundred and Twenty-Five Crores Only.

3.3. LAND ACQUISITION:

To execute the work, it is required land and structure acquisition and cost of Rs. 6.56 Crores.

3.4. MATERIAL RATES

The Original basic price (Ex-Factory) of cement, steel and bulk bitumen exclusive of all taxes and duties considered are as per Uni SR 2023-24. The difference in rates will be added to/subtracted from the basic rates in the SR.

Chapter – 4 – FIELD SURVEYS AND INVESTIGATION

4.1. General

In order to arrive at a feasible traffic improvement measure at –

- **Proposed Elevated Corridor from Hudson Circle to Minerva Circle.**
- **Proposed flyover from Anand Rao Circle to Nrupatunga Road Via KR Circle.**
- **Proposed flyover from Bala Gangadhara Swamy (BGS) Flyover to JC Road flyover.**
- **Junction improvement at Lalbagh West Gate.**

Studied the available data and conducted various field surveys and investigations in the month of September-2025.

4.2. Site Appreciation

The project under consideration is between Minerva Circle to Anand Roa Circle Via, JC Road-Nrupatunga Road-Sheshadri Road and SJP Road, KG Road & Kastruba Road. The location being central part of the city, traffic flow in this corridor is from southern Part of Bangalore towards Kempegowda Road, Vidhana Soudha, M.G Road, Mysore Road, and Sheshadri Road Also, the Present traffic flow pattern from other direction, i.e., traffic from Anand Rao Circle, KR Circle is such that, it has to go via Lalbagh to reach southern parts i.e., Jayanagar, Basavangudi, Banashankari JP Nagar, etc.

Proposed elevated Stretch is around 6.8km length which Crosses 10 major junctions (i.e, Minerva Junction, Urvashi Theatre, Shivaji Talkies Junction, Town Hall Junction, SJP Road Junction, NR Square Junction, Ulsoor Police Station, Hudson Circle, KR Circle, Maharaji College Junction, Freedom Park Junction & Lalbagh west Gate junction)

Type of Junctions

Name of Junction	Type of Junction
Minerva Junction	5-Legged junction
Bharat Talkies Junction	4-Legged Junction
Shivaji Talkies Junction	4-Legged Junction
Town Hall Junction	T type 3-Legged junction
NR Square Junction	4-Legged Junction
Ulsoor Police Station	K type junction
Hudson Circle	Grade Level Island in the form church which connects 8 roads round
SJP Road Junction	3 Legged Junction
KR Circle	5- Legged Junction
Maharani College Junction	4 Legged with Existing Underpass
Freedom Park Junction	T- Junction
Lalbagh West Gate junction	5- Legged Junction

ROW and Gradient of Existing Roads along the Stretch

Name of Road	Gradient	ROW
RV Road	Falling towards Minerva Junction	19.4m to 25.7m
Diagonal Road	Flat in nature	18.3m to 21.6m
Lalbagh Fort Road.	flat in nature	17.3 to 20.7m
JC Road	Falling gradient from Minerva Junction to Shivaji Talkies Junction. Further gradient increases upto KG road along townhall, Ulsoor Gate.	• 20.7m to 31.7m from Minerva Junction to Bharath Talkies Junction. • 22.3m to 23.5m from Bharath Talkies Junction to Shivaji Talkies Junction. • 20.8m to 60m from Shivaji Talkies Junction to Town Hall junction. • 25.6m to 26.19m Town Hall junction to NR Square junction. • 59.6m to 62.11m in between NR Square to Hudson Circle

KG Road	Falling gradient towards Mysore Bank Junction	28.84m to 33.95m from Hudson Circle
Nrupatunga Road	Falling gradient towards Hudson Circle.	22.3m to 25.8m
Kasturba Road	Falling Gradient from Hudson circle towards Kanteerva Stadium	25.5m
Rajaram Mohan Roy Road	Gradient slightly falling towards Richmond circle	27.55m 31.3m
SJP Road	Gradient slightly falling towards KR Market	36m to 56m
Sheshadri Road	From Palace Road gradient falling both side (i.e., from Palace Road to KR Circle and from Palace road towards Anandrao Circle)	32m to 42 m
Dr. Ambedkar Road	Raising gradient from KR Circle to Vidhanasoudha	31.5m to 33m

Lalbagh West Gate	At Junction along RV Road gradient it flat. Towards Vanivilas road slight fall and towards MN Krishna Rao road slightly increases Towards Krumbigal road slight fall	a) RV Road – 22.0m to 22.5 b) Krumbigal Road -13.5m to 19.2m. c) Vanivilas road – 22 to 23.5m

4.2.1. CORRIDOR JUCTIONS PHOTOS

@ MINERVA JUNCTION

<table>
<tr><td> </td><td> </td></tr>
<tr><td>From RV Road</td><td>From VV Puram / Diagonal Road</td></tr>
<tr><td>
</td><td> </td></tr>
<tr><td>From Lalbagh side</td><td>From Kalasipalya Side</td></tr>
</table>

Along JC Road

<table>
<tr><td> </td><td> </td></tr>
<tr><td>JC Road</td><td></td></tr>
<tr><td> </td><td> </td></tr>
<tr><td>At town hall</td><td>Badami house junction</td></tr>
</table>

@ HUDSON CIRCLE

From NR square	Towards Lalbagh Road and Kasturba Road
Towards KG Road	At Ulsoor Gate Police station

@ KR CIRCLE

Towards Anand Rao Circle	Towards Anand Rao Circle
Towards Vidhana Soudha	

@ LALBAGH WEST GATE

Towards MN Krishna Rao Road

Towards RV Road

Towards Krumbigala road

4.2.2. Major Utilities along the corridor: -

- On JC Road One Storm Water Drain Cross the proposed project at Ch: 1000, having with of 10m wide.
- Pedestrian Skywalk at Opposite to LIC Building, Kasturba Road, Rajaram Mohan rai road, Sheshadri Road.
- Having Pedestrian Underpass at SJP Road, Nrupatunga Road, and Sheshadri Road.
- Having Vehicular underpass at KR Circle and Palace Road Junction.
- Presently Green line metro functioning at first level along RV at Lalbagh west gate junction.

4.3. Reconnaissance Survey

A reconnaissance survey was carried out along the project road to appreciate them and to finalize the locations of the field surveys and investigations. The project appreciation of the project road was presented in the Inception Report submitted. The existing condition and features of the project road is discussed in this section.

The Consultant's team members with Key professionals have inspected the site on Sept 8th 2025 to familiarize themselves with the site conditions and gather necessary field information and for planning various investigation activities to be performed for preparing various reports. This includes activities like Road Inventory, Existing pavement conditions, possible re-alignments where the existing road geometry are inadequate. The specific observations made by the team members belonging to Highway, Geo technical and materials, Pavement, Surveying, bridge group, social and environmental group and Traffic were presented in the Inception Report.

The team continued with additional field visits and collected data from BBMP / BWSSB / BESCOM / KPTCL / BSNL other agencies. The data being gathered include right of way details, land records, road construction history, available material sources, planned improvements on the project road like ramps, re-alignments, development plans in the project corridor. During the field

reconnaissance survey, stretches requiring realignment have been identified.

- The Traffic at Minerva Junction is controlled by Signals.
- J.C Road is one way from Minerva Circle to Town Hall junction.
- Heavy commercial establishments are present on either side of the J.C Road.
- The parking banned on J.C Road.
- Multi-level car parking, built by M/s. BBMP, is located on J.C Road.
- J.C Road has footpath on either side.
- Town Hall junction is controlled by signal.
- Puttannachetty Town Hall, Canara Bank Head office, are located at Town Hall junction.
- LMV vehicle from S.P Road enters N.R Square via road adjacent to Dasappa Hospital.
- N.R Square junction is controlled by Signal.
- Except the arm connecting town hall, all other arms are one way at the N.R Square junction.
- Nrupatunga Road, Kasturba Road, Pallavi Theatre Road, and Devanga Hostel Road are all one way at Hudson Circle junction.
- The traffic is very heavy, particularly with cars and two wheelers is between Minerva Circle and Hudson Circle.
- SJP road is one way, traffic are allowed from KR Market side to Town Hall and having park on right side for traffic, parking is allowed on LHS while coming from KR market
- NR Road is one from Town Hall to KR Market.
- Two-way traffic on sheshadri road, also parking is banned.

- Dr. BR Ambedkar Road is also having two-way traffic.
- Lalbagh west gate is 5 legged junctions with controlled automatic traffic signal, krumbigal road is one.
- There are pedestrian subways along Nripathunga road and Sheshadri road, which requires to be considered during the planning stage
- There is single lane LUS from Ambedkar road to Nripathunga road crossing KR Circle.

4.4. TOPOGRAPHICAL SURVEY: -

Topographical survey was conducted establishing control points along the corridor using DGPS for X, Y coordinates and Z coordinate is established with respect to MSL from the known point of elevation.

Site features as been captured using total station and levelling data was collected using auto level.

The following features were collected during survey:

- Existing road pavement surface, its variation in width along with all other relevant road
- details like centreline of carriageway, pavement edge, embankment/cutting edges top
- and bottom, side drains, signs, km posts etc.
- Location of traffic islands, median, police chowks, within limits of ROW.
- All religious places – churches, Towers, Parks, and Heritage Buildings etc., including
- location, building lines and clear dimensions of compound walls and extensions.
- Trees (position, species and girth measured 1.2m from ground level) Tree Species and
- type of crops.
- Building fronts and outlines (to be classified by construction type i.e., RCC/tiled
- house/thatched house etc with number of storey).

- Electric transformers, mast, tower, etc.
- All telephone lines. OFC lines, Private OFC lines, Water Pipes including manholes above the ground belonging to layouts/ colonies/nagars and other bodies, electricity lines etc.

Levels along the alignment were taken at every 20m intervals and at all intermediate breaks along the centre line of the existing alignment. Spot levels were recorded at critical points such as horizontal curve start, centre and end points and vertical curve start, centre and end points.

Cross sections, covering drain to drain on either side of service road or compound to compound or building line which ever was more, were taken at intervals of 20 m in general with levels at 5m c/c. Cross sections were taken at the centre line of all culverts and at all critical points, mentioned earlier.

Details of the topographical survey are shown in drawing VAX/B-SMILE/TOPO-01 which is enclosed along with drawings volume.

4.5 TRAFFIC SURVEY

4.6.1. Project Background

Traffic studies are the initial step of any road project whether it is improvement/upgradation over existing road. This generally considered by way augmentation of existing capacity of road such that, the road would handle the present and future traffic in acceptable level of service. In order to decide upon the type of improvement or upgradation required needs some base line studies related to traffic volume and its composition. These traffic studies are the base for deciding many components such as roadway width, lane width, pavement design etc. All these signify the importance of traffic data. Traffic flow on rural section is different when it is compared with that of an urban road section. In the urban areas, the traffic flow is frequently interrupted with close intersections and continuous ribbon development. When there is a ribbon development is majorly a commercial establishment, this will also affect the through traffic along the corridor due to parking or stopping near commercial establishment. All these conditions warrant for congestion and delay in the traffic flow thereby increase in the travel time leading to unnecessary increase in Vehicle Operation Cost. Presently, the study is under consideration is pertaining to an urban section of an important arterial road in the Bangalore City which has similar type of ground condition and carry maximum volume of passenger vehicles specially Two-Wheelers, Autos and Cars. The proposed project road forms a critical link within the City Centre to southern part of Bengaluru city. It covers a stretch of –

The road which needs immediate attention is part of -

a) Jaya Chamarajendra Road (JC Road) from Minerva Junction to Town Hall Junction and further upto Hudson Circle via Town Hall.
b) loop flyover from existing Bala Gangadhara Nath Swamiji flyover to Townhall
c) Elevated Corridors from Sangolli Rayanna circle (Anand Rao Flyover) to Nrupathung road (KR Circle).
d) At Grade Junction improvement at Lalbagh west.

It is observed that, there are 11 number of major junctions are covered at very closely leading to frequent traffic congestion in proposed stretch.

4.5.2 TRAFFIC SURVEY LOCATIONS.

Traffic surveys have been carried out on the project corridor in order to identify present and likely future scenarios so as to device suitable remedial measures and to evolve appropriate design method. The primary objectives of these traffic surveys are to determine the characteristics of traffic movement on the project corridor determine the turning movement pattern of traffic at road intersections.

As per the present traffic flow pattern following have been observed;

- The traffic is allowed flow from Minerva Junction to Town Hall in one direction only.
- From Town Hall Junction to Hudson Circle, the traffic is allowed in both directions.
- From NR square to Jayanagar, Basavangudi, the traffic is allowed on Lalbagh Main and krumbimgal road by west gate of labagh.
- At all the junctions mentioned above, the traffic flow has been restricted in many directions due high volume of traffic flow. The details of traffic flow are presented in subsequent sections.

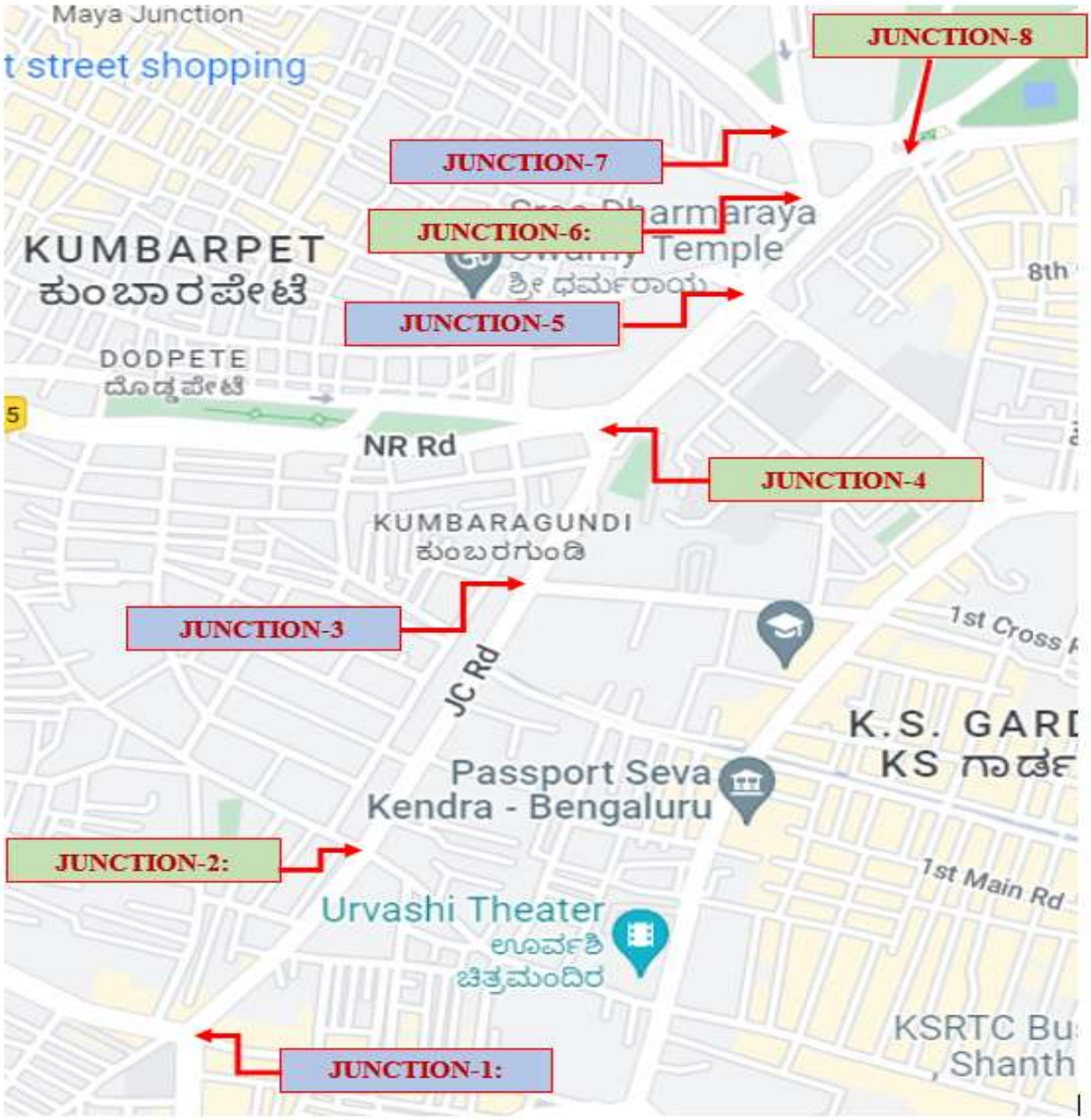


Figure 4-1: Details of Project Stretch

Detailed Traffic Analysis Report is enclosed as Appendix -1.

4.5. Soil Investigation

Geo - technical investigations were carried out at structure locations through exploratory borings as per the stipulations given in

- Clause 4.11.4.4 under GEO-TECHNICAL INVESTIGATIONS AND SUB-SOIL EXPLORATIONS
- IS: 1892 – 1979: CODE OF PRACTICE FOR SUB-SURFACE INVESTIGATION FOR FOUNDATIONS, and
- The specifications given in Clause 1102.1 of SPECIFICATIONS FOR ROAD AND BRIDGE WORKS (Fifth Edition)

The results of the soil investigations are enclosed as **Appendix -2.**

4.6. Roadside Investigations

Preparation of road inventory of the project road was undertaken first. The purpose of the survey was to obtain the necessary information regarding the road features along the project road, condition and performance of drainage structures and other ancillary road features like footpath, median, kerbs etc. An integrated program to carry out surveys and investigations were developed, using IRC SP -19 as a general guide.

The following information was collected as part of the survey

- Carriageway width
- Shoulder widths
- Surface type for carriageway and shoulders
- Embankment or cut and approximate height

- Location, type and condition of side drains
- Location and type of road access and roadside features (parking bays, bus stops, and all major and minor commercial establishments)
- Roadside land use (agriculture, barren, built-up. slum areas, urban)
- Presence of crossing traffic (vehicular, pedestrian).

Chapter – 5 – ALIGNMENT

5.1. General

Traffic data collected at the junction from the traffic survey and its analysis shows that the intersection remains congested for considerable duration of the day. The volume of traffic is expected to increase, as a result of which congestion and delays at the junction increases. This would further lead to increased level of pollution and accidents. It is the right time for taking up necessary measures to reduce the congestion at the intersection by enhancing the capacity/ reducing conflicts and delays at the junction in order to avoid future traffic problems. The capacity of an intersection can be increased by segregating major conflicting traffic movements and segregation of traffic can be achieved by the construction of grade separators.

5.2. Constraints at Site

The following constraints were kept in mind while deciding on the alignment for improving traffic circulation at following locations-

- Elevated Corridor from Hudson Circle to Minerva Circle.
- Proposed flyover from Anand Rao Circle to Nrupatunga Road Via KR Circle.
- Proposed flyover from Bala Gangadhara Swamy (BGS) Flyover to JC Road flyover.
- Grade level junction improvement at Lalbagh west gate.

- There are commercial Establishments on either side of the JC road.
- Puttannachetty Town Hall building on Heritage Building of Bangalore city is along the corridor under study.
- "KEMPEGOWDA STATUE" at N.R Square is along the corridor under study.
- "Hudson Memorial Church" and "Kempe Gowda Tower" at Hudson Circle.
- At NR Square junction and Kasturba Road, there are Pedestrian Sky walks.
- At Town Hall Junction, having shorter distance from town hall junction & Dasappa hospital junction / SP road to accommodate down ramp from Elevated Road. To avoid bottle neck at SP Road, it has been proposed to integrate BGS flyover and JC Road elevated corridor by providing connecting loop from BGS flyover to JC Road.
- There are educational institutions and State and Central Government office establishment on either side of the road from Anand Rao Circle to Hudson Circle via KR Circle.
- Green line metro function at 1st level along RV Road at Lalbagh west gate.
- **KG Road Ramp shall be integrated with proposed tunnel road project.**

5.3. ALIGNMENT

5.3.1. PLAN & PROFILE FOR ELEVATED CORRIDOR FROM HUDSON CIRCLE TO MINERVA CIRCLE AND LOOP FLYOVER FROM EXITING BGS FLYOVER TO TOWNHALL.

5.3.1.1. Advantages

1. Reduced V/C ratio at the Surface level road at 7 junctions along JC Road (i.e, Minerva Junction, Urvashi Theatre, Shivaji Talkies Junction, Town Hall Junction, NR Square Junction, Ulsoor Police Station, Hudson Circle)
2. Decongestion of surface level traffic there by advantage for Public transport vehicle, mainly for BMTC. With the Priority bus lane along JC road, buses can be hassle free and it will be greatly helpful forAMBULANCE movement, as it can move along priority lane.
3. Less signal time and queuing length along JC road from Minerva to Hudson Circle for surface level traffic.
4. It Reduce the travel time along corridor, both from Minerva junction to Hudson circle and Anand rao circle to RV Road.
5. Interchange of traffic at One level with High level Rotary at Hudson Circle.
6. Construction will be smooth at Badami house with the proposal of Rotary otherwise, loop from Nrupathunga road should have been taken at second level.
7. It is proposed 2-lane carriageway with 7.5m for down ramp and up ramp of 6m wide carriage way to suit 2 lane traffic of urban road standard at RV Road to reduce land acquisition.
8. It proposed is 2 lane carriageway loop from BGS flyover to Townhall for through traffic, with which the traffic from Mysore can approach

the elevated road and take the appropriate ramps to reach, northern and eastern parts of Bangalore with out getting into traffic stream along NR road, up to Hudson circle.

9. The corridor allows smooth movement from South Bangalore to Central Bangalore, North and east Bangalore and vice versa without traffic signals, ensuring faster travel time.

10. Further it proposed grade level junction improvement at Lalbagh west junction for smooth traffic movement at grade level, in view of no space of additional grade separator proposal, it has green line metro function along RV road and Vanivilas Road at 1st level.

11. At grade local traffic along JC road from Minerva circle to town hall, SJP Road, KG Road, while through traffic shifts to the elevated corridor, ensuring balanced traffic distribution.

12. **The proposed alignment is connected to the proposed Tunnel facility by B-Smile which is being proposed from Sarjapura road to Hebbal. Since this corridor is connected to Tunnel at KG Road, this facility will be useful for the traffic going up to Hebbal from south part of Bangalore city.**

5.3.2. PLAN & PROFILE FOR FLYOVER FROM ANAND RAO CIRCLE TO NRUPATUNGA ROAD VIA KR CIRCLE.

The Alignment shown above is the only feasible solution to ease the traffic congestion at junctions as there are constraints to have different options.

Advantages

- Through traffic from Anand Rao Circle to Nrupathunga road will take this facility avoiding 3 major junctions, Palace road and very importantly KR circle, there by reduction of travelling time and waiting time. There will be through access to traffic from Dr. BR Ambedkar Road crossing KR circle. Both traffic can take the proposed elevated corridor from Minerva circle to Hudson circle , there by direct access to southern part of the Bangalore city avoiding 8 signals.
- The load on surface-level junction operations will be minimized, reducing congestion at the intersection be providing elevated corridor.
- Since the through traffic is segregated, the signal cycle length at KR Circle can be reduced, minimizing overall waiting time.
- Removal of conflict points for through traffic reduces chances of accidents and improves pedestrian and vehicular safety at ground level.
- Proposed elevated road is 2-lane unidirectional flyover, which is place at Centre of median to avoids interference with service road at grade level user to making effective use of available space.

- Main corridor users benefit from uninterrupted travel, while cross road users still maintain access with signalized control, balancing mobility and accessibility.

Chapter – 6– PLANNING AND DESIGN CRITERIA

6.1. Planning Grade Separator /Elevated corridors

One or combination of the following usually guides planning of grade separator in urban areas:

- Elimination of conflicting traffic streams of traffic
- Hierarchy of the intersecting roads
- Intersection traffic characteristics
- Present development level and proposed development pattern for the influence area
- Lack of alternative routes / modes
- Feasibility with respect to available space and minimum land acquisition
- Utilities present at the project location, feasibility of shifting / relocation
- Other major infrastructure projects planned
- Cost and Economic considerations
- Traffic diversions and management during construction

6.2. Planning Criteria

The following paragraphs briefly highlight the various Design considerations and standards used for the present proposal. However, it is important that the preamble to Design criteria is clearly understood in the context of urban development –especially with due consideration to traffic, existing road network, development pattern, right of way, rise and fall of road etc.

The Indian Roads Congress and the Ministry of Surface Transport and Highways specify various guidelines and specifications for flyovers, junctions and other facilities pertaining to flyovers. These specifications are largely based on the theoretical considerations and ideal situations which can hardly be obtained in urban situation for a city like the present one. Hence, in the present proposal, certain changes and modifications in the Design standards are reviewed keeping in view the site constraints.

6.3. Design Standards - Roads

Design standards for the Design of Horizontal and Vertical Geometry and other road elements are used referring following guidelines of Indian Roads Congress-

IRC: SP-90

IRC: 92

IRC: 86

IRC: 73

IRC: 38

Design standards considered are briefly stated below.

6.4. Geometry

The horizontal geometry will be designed in accordance with Clause 10 of IRC:86-2018. Following considerations are made in horizontal geometry design

- Minimum disturbance to existing structures which are already constructed based on inputs from B SMILE in various meetings / discussions.
- To maintain existing road horizontal profile to the extent possible.
- Road widening considering building lines on either side of existing carriageway.
- Rise and fall of existing road in design of the facility;

6.5. Design Speed

The design speed for elevated road/grade separator in urban stretch is generally governed by the existing road plan and building lines. The most critical sections governing the design speed is the turning movement of vehicles on curves and available sight distance to traffic approaching the junction. Considering above factors, design speed of 60 Kmph is adopted in general, except at sharp turnings and at exceptional locations where site constrains, minimum speed of 30 Kmph is followed.

These constrained locations are considered in alignment design considering ground constraints like building lines, land acquisition and utilities.

6.6. Horizontal Alignment

Horizontal alignment for the grade separator is designed in accordance with IRC:38-1988 "Guidelines of Design of Horizontal Curves for Highways and Design Tables". Clause 10.3 of IRC:86-2018 specifies minimum curve radius of horizontal curve for 60 Kmph as 70m for 4%

super-elevation. These guidelines will be followed for reasonably flat and less winding alignments. Depending on site constraints modifications are made for providing tighter curve radius wherever required based on site specific considerations. For ramps, curve radius corresponding to 20 Kmph design speed is proposed.

6.7. Super Elevation on Curves

Super-elevation on horizontal curves will be attained as per IRC: 38-1988. The super elevation will be limited to 4 % as per CI 10.2 of IRC:86-2018 as the project area is in urban section.

6.8. Cross-Sectional Elements of Elevated Corridor.

Width of Elevated Corridor has a direct relationship with the traffic volume it is expected to serve and width available at ground level based on land acquisition. Widths of Elevated Corridor / Flyover for various categories are as shown in Table 6-1.

Table 5.9.1 Cross Sectional Elements of Deck

Lane Type	Carriageway Width	Kerb & Crash Barrier	Total Width (m)
Main Flyover - 4Lane (Two-way Bi-Direction) (along JC Road)	2 x 7.5 m	0.5m x 2 sides + 1.0m Median	17.0m
Loops - Intermediate/ 2	6.0 m & 7.5 m	0.5m x 2 sides	7.0 m & 8.5m

lane unidirectional at RV Road, diagonal Road and Loop from BGS Flyover			
Rotary - 4lane Unidirectional	14 m	0.5m x 2 sides	15.0m
Entry Ramp – 2-lane Unidirectional at Nrupatunga Road and Rajarammohan Roy road.	7.5m	0.5m x 2 sides	8.5m
Exit Ramp – 2- lane Unidirectional at KG Road and Kasturba Road.	7.5 m	0.5m x 2 sides	6.5m

6.9. Surface Level Road

The surface level road will carry local remaining traffic (traffic using shops and commercial establishment, cross road). The width of surface level road will depend on the traffic at the surface level after the flyover is constructed and mostly on space availability. However, for the existing traffic at different sections in the corridor, the lane requirement would

be enormous. This involves land acquisition to larger extent considering the highly developed area with many high raised buildings.

The footpaths available will have to be re-planned to provide the required space. Therefore, a minimum of 7.0m carriageway at surface level along main trestle with 2.0m Drain cum footpath and minimum 5.5m carriageway at surface level along ramps with 1.5m Drain cum footpath

With the provision of white topping of grade level road along Corridor, junction improvements, Kumbaragundi Road, Lalbagh Fort Road, JC Road to Double Road via Urvasi Theatre, 1st Cross Road Sampangi Ram Nagar is proposed.

6.10. Cross Slope

The deck and approaches is proposed with 2.5% cross slope.

6.11. Vertical Alignment

The vertical geometry of the flyover / underpass is designed as per guidelines given in IRC: 92-1985. Clause 5.1.2 of IRC: 92-1985 states that the vertical gradient should be desirably kept at 4%, but in no case exceed 6%. Vertical curves are provided at locations of change in gradient. The length of vertical curves is dependent on change in grade between two vertical straight and this will be as per IRC SP: 23-1993 "Vertical Curves for Highways".

Vertical Clearance: A minimum of 5.5m vertical clearance for vehicles at grade traffic is ensured in viaduct portion of the proposed elevated corridor.

6.12. Approach Ramp

It is proposed to adopt "Reinforced Earth" type retaining structure for the approach ramp. The reinforced earth facia wall made of precast concrete panels offers great scope for a variety of aesthetic treatments in the form of panel shapes and colour. Apart from aesthetics, it improves the speed of construction.

Approach gradient of grade separator is primarily dictated by the following.

- Space available in the approach road
- Distance available to nearest major intersection.
- Access for cross roads, bus stops or other important buildings.

Clause 11 of IRC: 86-2018 specifies that the maximum vertical grade in urban area should be limited to 1 in 25. Approach longitudinal gradient of 1 in 30 will generally be attempted for surface level roads to account for the mixed form of traffic present in the city. However, considering the project location, type of vehicles (Majority of 2 Wheelers and 4 Wheelers) ramp of 1 in 20 is proposed as per the discussion with B SMILE to minimise the cost of construction and cost of land acquisition

However, in situations, where the ramp length needs to be curtailed due to proximity of adjacent intersection or similar cases, the slope might require to be restricted.

6.13. Design loads For Structure

- **Dead Loads**

Self-weight = 25 kN/m^3

Crash Barrier = 7.75 kN/m

Wearing Coat = 2 kN/m^2

- **Vehicular Live loads**

The design is carried out for IRC vehicular live loads as per IRC 6:2017 corresponding to various traffic lanes i.e Intermediate Lane (5.5m carriageway), 2 Lane (7.5m carriageway), 2 Lane with paved shoulder (11m carriageway), 4 Lane Bi-directional carriageway (2 x 7.5m).

Impact factor considered as per IRC-6-2017, corresponding to Class A & Class 70R Vehicle.

- **Wind forces**

Wind forces have been considered as per IRC: 6 – 2017 and subsequent amendments in the latest edition of Indian Highways.

The appropriate wind force on Superstructure and substructure are considered as per CL 209 IRC 6 : 2017 with a basic wind speed of 33m/s corresponding to Bangalore location.

- **Seismic force**

The structure has been designed for the seismic force as per the provisions of IRC-6-2017, corresponding to seismic zone – 2.

- **Temperature range**

i) For design of structure to account for temperature in formula, (ΔL) = α Lt,

The value of T shall be (+/-) 29.55/25.55 degree centigrade.

Where α =Coefficient of expansion or contraction = 1.2×10^{-5}

L =Length of the member

(ΔL) = Expansion / Contraction due to temperature variation in appropriate units.

ii) The super-structure is also designed for effects of distribution of temperature across the deck depth.

- **Vehicle Collision Load:**

It is proposed to provide suitable fencing system taking in to account its flexibility having a minimum height of 1.50m above the grade level carriage way and according the piers are designed for residual load component, with vehicles plying with speed limit of 30 Kmph as the road at grade are city roads, as per art 225.3.1, IRC: 6-2017.

- **Braking Force**

Braking Force is considered as per CL 211.2, IRC:6-2017. The horizontal load will be fraction of vertical reactions as per the guide lines of CL 211.2.

- **Friction Force**

Friction force is considered as per CL 211.50 IRC: 6 -2017

- **Centrifugal Force**

Centrifugal force will be as per CL 212 IRC: 6 -2017

- **Active Earth Pressure**

Active Earth Pressure will be as per CL 214.1.1 IRC: 6 -2017

- **Live Load Surcharge**

Live Load Surcharge will be as per CL 214.1.1.3 IRC: 6 -2017

6.14. Design Basis – Structure

6.14.1. Super Structure.

SL NO	DETAIL	DESCRIPTION
General Arrangements		
1.	Span Arrangement	50.0m for standard viaduct spans, except for adjustable spans of 40m, 30m is chosen for the corridor. 105.4 dia High-Level Rotary at Hudson Circle
2	Expansion Joints	Expansion joints are proposed.
2.	Carriage way	Four lane divided carriageway for main arm. Two lane carriageways for up/ down arms (at diagonal Road, RV Road, KG Road, Nruptunga Road, Kasturba Road, Rajaram Mohan Roy Road and BGS flyover loop) 2- lane carriageway for main arm from Anand Roa Circle and from Dr. BR Ambedkar Road joins at KR circle and further continue in 3-lane on Nrupatunga Road till exit to Ground level.
3.	Crash Barrier / Median	RCC Crash Barrier on either side and central 1000mm wide RC median
4.	Overall width of deck.	17.00m for main arm.

5.	Type of superstructure.	**Fish belly type Box Girder UHPFRC and HPC for standard spans of various deck width of 17m wide deck elevated corridor / flyover and for 7.0m, 8.5m and 12.0m wide deck U Box Girder UHPFRC and HPC deck.** **Structural Steel Box Girder for High-level Rotary, Adjustable Spans are with composite steel girders.**
6.	Overall depth of superstructure.	2.3 to 2.6m depth.
7.	Minimum thickness of deck slab.	250mm.
8.	Cross Drainage	2.5% camber in straight with drainage spouts at the end of carriageway with down take pipes to convey the way to grade level drains.
9.	Wearing Coat	Bituminous Concrete uniform thickness 50mm in single layer on 4mm thick mastic pad.
10.	Noise Barrier	Noise Barriers proposed along the project road for site face properties.
Loads considered in designs.		
1.	Dead Load	25 kN/m^3 for RCC 22 kN/m^3 for asphaltic wearing coat.

2.	Superstructure live load.	Superstructure designed for IRC:70R & Class 'A' Vehicle
3.	Load combination	DL + SDL + VhLL.

Material adopted.		
		Steel – Fe550 for all structures Low Relaxation Class 2 Strands are proposed For Pre-stress steel <u>Superstructure</u> <u>For Main arm, Entry and Exit Ramps</u> **UHPFRC – M150 for U-Trough with M150 strength** HPC M50 for deck slab and end diaphragm <u>For Rotary Superstructure</u> E350 Structural steel <u>Substructure</u> M50 for Pier and Pier Cap M35 for Pile and Pile Cap Crash Barriers are in M40 Grade Concrete.
Permissible stresses:		

1	In Concrete – Flexural	IRC 112-2020 (CL 12.2)
2	Permissible Tensile stresses in case of PSC	As per IRC 112-2020 (CL 12.1) at locations other than segment joints
	Under Transfer Condition	
	Under Service Condition, with Frequent Combination As per Table B.3 of IRC 6-2017 (column 3)	As per IRC SP 65 - 2018 (CL 3.2) at segment joints
	Under Service Condition with Rare Combination As per Table B.3 of IRC 6-2017 (column 2)	As per IRC SP 65 - 2018 (CL 3.2) at segment joints
3	Crack Width	As per IRC: 112-2020 (Cl:12.3.4)
4	Flexural Tension	As per Table 6.5 IRC 112-2020
5	Modulus of Elasticity, Ec	As per Table 6.5 IRC 112-2020
6	Permissible Direct Compressive Stress	As per IRC-112 (Cl:12.2.1)
7	Maximum permissible shear stress	As per IRC-112 - 2020(Cl:10.3.2 and 10.3.3)

8	Permissible shear stress without shear reinforcement.	As per IRC-112 - 2020 (Cl:10.3.2)
9	Elastic Modulas of Steel	As per IRC-112 - 2020 (Cl:6.2.2)
F	Structural Design	
1	Design will be carried out by limit state method as per IRC-112	
G	**Expansion joint:**	
I	Slab Seal type as per MOST/IRC specifications, also conforming to recent amendments of MoSRT&H, Transport Bhawan, New Delhi.	
H	**Bearing Data**	
I	Type of bearing	POT Cum PTFE/Spherical bearings conforming to IRC 83: (part III/IV), also conforming to recent amendments of MoSRT&H, Transport Bhawan, New Delhi.
I	**General Design Requirements Provided**	
1	Minimum clear cover for any reinforcement	40mm for super structure 75mm for foundation
	Concrete Cover to Post tensioned ducts	75mm
2	Minimum tensile reinforcement in beams	As per IRC:112-2020 (Cl:16.5.1.1)
3	Minimum shear reinforcement	As per IRC-112 - 2020 (Cl:16.5.2)

4	Minimum and Maximum reinforcement bar sizes	As per IRC-112 - 2020 (Cl:15.5.2.2)
5	Reinforcement bar spacing	As per IRC-112 - 2020 (Cl:15.2.1)

6.14.2. Substructure.

Substructure system.		
Load considered in design.		
1.	Dead loads from superstructure – (G1)	
2.	Superstructure imposed loads from superstructure – (G2)	
3.	Vehicular live load from superstructure – (G3).	
4.	Self Wt of pier system – (G4)	
5.	Braking load from vehicular traffic – (fb)	
6.	Wind loads	As per IRC – 6-2017 for wind speed of 33m /sec.
7.	Seismic effects	FeQ. Zone factor – 0.10

		Damping – 5%. Importance factor – 1.2.

6.14.3. Foundation.

SL NO.	DETAILS	DESCRIPTION
Foundation system.		Pile Foundation with Bored Cast in situ Piles as per relevant Codal Practice
Loads considered in design		
1.	Dead loads from superstructure – (G1)	
2.	Superstructure imposed loads from superstructure – (G2)	
3.	Vehicular live load from superstructure – (G3).	
4.	Self Wt of pier system – (G4)	
5.	Self Wt of foundation - (G5)	
6.	Braking load from vehicular traffic – (fb)	

7.	Wind loads	As per IRC – 6-2017 for wind speed of 33m /sec.
8.	Seismic effects	FeQ. Zone factor – 0.10 Damping – 2%. Importance factor – 1.2.
material adopted		M50, M35 grade of concrete, Fe550 grade steel & Low Relaxation Class 2 Strands are proposed For Pre-stress steel
Limiting stresses		
1.	In concrete flexural compression.	16.8 Mpa for M35 concrete as per IRC-112 2020
2.	Allowable stress in Steel	440 Mpa for Fe 550 steel as per IRC – 112-2020
Limit State Design is Adopted for foundation As per IRC- 112. Load Combinations as per IRC:6 2017, Table B 3.1 to B 3.3		

6.14.4. General Design Criteria

general design criteria's	
1.	Maximum pile capacity (Vertical, Horizontal and Uplift) are as per Geotech report and increase in pile load for wind & earth quake considered as per IRC – 78-2014

2.	Clear cover for reinforcement	75mm.

6.14.5 Pavement Design:

The flexible pavement is designed as per IRC:37-2018 for a cumulative design traffic of 30 MSA and a subgrade soaked CBR = 8% (reliability, lane distribution and growth assumptions as per code). Shoulder and drainage provisions are compatible with the main carriageway to preserve the design life.

Pavement crust: - proposed curst details

Bituminous Concrete (BC): 40 mm

Dense Bituminous Macadam (DBM): 95 mm

Wet Mix Macadam (WMM): 250 mm

Granular Sub-Base (GSB): 200 mm

Prepared Subgrade: 500 mm

6.14.6 Overlay

An asphalt overlay is proposed over the existing carriageway to restore structural capacity and riding quality. The design follows IRC practice for overlays on flexible pavements.

Bituminous Concrete (BC): 40 mm

Profile correction Course Dense Bituminous Macadam (DBM): 60 mm

6.15. Reference Codes

- IRC:37-2018 "Guidelines for Design of Flexible Pavements"
- IRC: 86-2018 "Geometric Design Standards for Urban Roads and Streets"
- IRC: 92-2017 "Guidelines for the Design of Interchanges in Urban Areas"
- IRC: 106-1990 "Guidelines for Capacity of Urban Roads in Plain Areas"
- IRC: 5 – 2015: Specifications and Code of Practice for Road Bridges (Section-I)
- IRC: 6 – 2017: Standard Specifications and Code of Practice for Road Bridges, Section-II Loads and Load Combinations.
- IRC: 112 – 2020: Code of Practice for concrete Road Bridges
- IRC: 78-2024 Part 1: Standard Specifications and Code of Practice for Road Bridges, Foundation and Substructure.
- IRC: 78-2020 Part 2: Code of practice for limit state of design of foundations
- IS: 456 - 2000 Code of Practice for Plain and Reinforced Concrete
- IS: 2911 (Part I/Sec 2) - 2010 Code of Practice for Design and Construction of Pile Foundations
- IRC: 83 (Part - III) and Part IV: Code of Practice for Road Bridges-Section IX – POT cum PTFE Bearings and Spherical Bearings
- IRC: Sp-65 - 2018: Guidelines for Design and Construction of

Segmental Bridges

- **NF P 18-470 – 2016: Concrete — Ultra-high-performance fibre-reinforced concrete — Specifications, performance, production and conformity**
- **NF P 18-710 – 2016: National addition to Eurocode 2 — Design of concrete structures: specific rules for Ultra-High-Performance Fibre-Reinforced Concrete (UHPFRC)**
- IRC SP-50 – 2012: For drainage Design
- SP 16 – 2019 Guidelines on Measuring Road Roughness and Norms
- IRC: 35 - 2015 for Road Marking
- IRC: 65- 2017: Guidelines for Planning and Design of Roundabouts for Road Signages

CHAPTER- 7 – STRUCTURAL SYSTEM OF FLYOVER

7.1 General

The proposed project is inside the city area. The following points are viewed in selecting structural system for the project –

- The Project under study is very important connection to various parts of the city and complete diversion of traffic is not feasible.
- The construction method and system shall allow the movement of vehicles during construction period with minimum hinderance.
- The construction shall be Precast / prefabricated and segmental to minimise the construction period.
- The precast / prefabricated units shall have high strength to weight ratio.
- Easiness of transportation and erection of precast / prefabricated units.
- Apart from above points it should suit urban architecture with minimum Span to depth ratio

7.2 Drainage System.

Presently Elevated Stretch is having both sides drain and we have not disturbed the flow and alignment of drain. Only proposed new drain where land acquisition / widening of road is necessity.

It is proposed Drainage spouts at interval satisfying the codal guidelines with PVC down take pipe connected to grade level drain to drain out the elevated road rain water.

7.3 Span Arrangement

Span arrangement of 60m and 50.0m is studied and discussed with authority, 50m span is proposed from the following point of view–

1. Depth of Super structure for 60m is 3.1m, looks bulky with vertical clearance of 5.5, which will affect the aesthetics.
2. Space required for foundation for longer span is more and inconvenience for road users during the construction.

7.3 Options of Super structure.

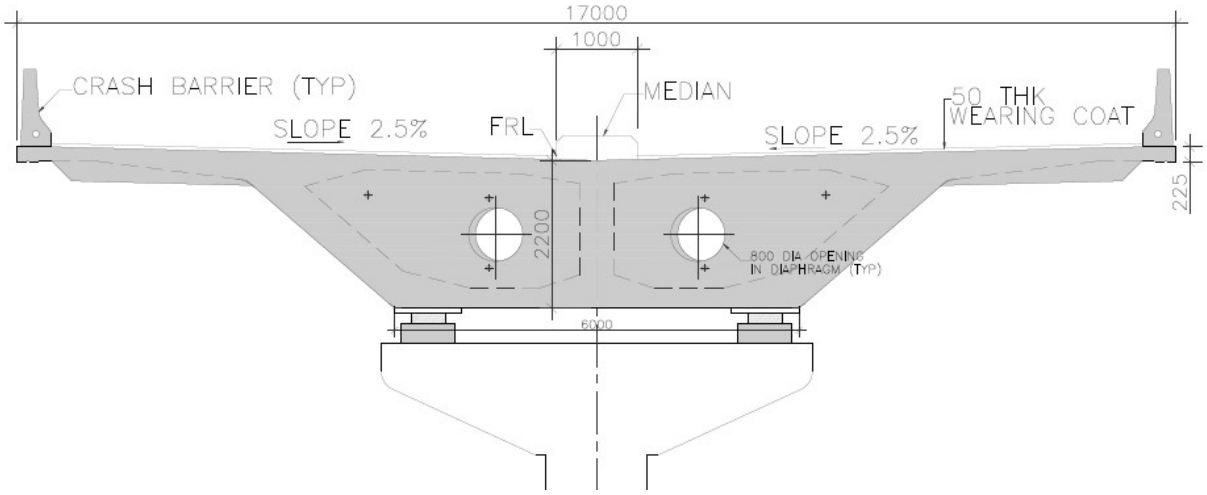
Following options are studied –

	Span	Structure Type
Option – 1	30	Segmental Box
Option – 2	30	Spine and Wing
Option – 3	45	Composite Steel Girder
Option – 4	50	UHPFRC

7.3.1 Option – I: Segmental Box Girder

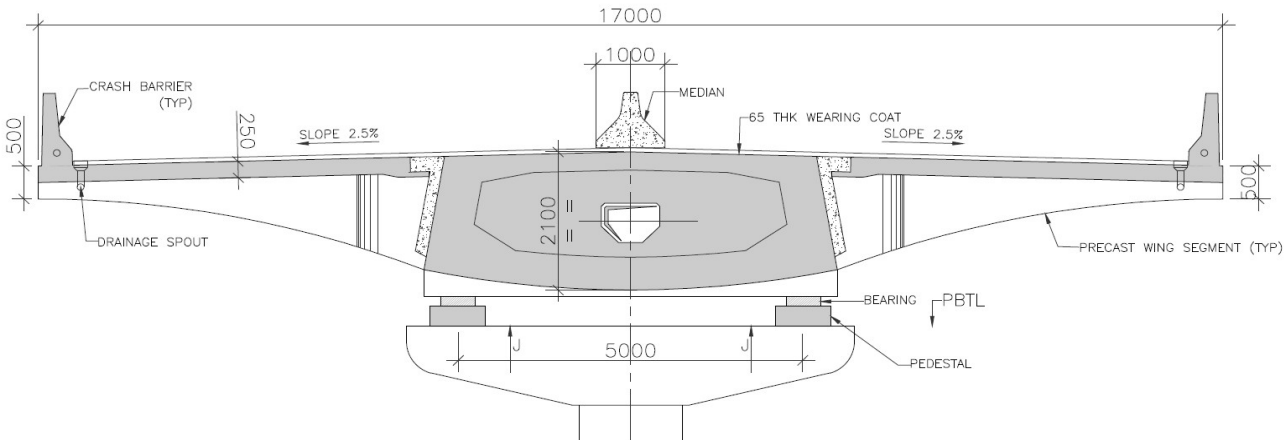
- Construction Speed: The use of precast segments allows for rapid on-site assembly, significantly reducing construction time.
- Traffic Disruption: Minimal on-site activity and a smaller footprint mean less disruption to traffic, making it ideal for urban areas.
- Quality Control: Manufacturing in a controlled factory environment ensures high-quality segments with consistent strength and durability.

- Aesthetics: The slim, clean lines of a segmental box girder can be aesthetically pleasing.
- Cost: The initial investment for casting yards and specialized equipment is high. **The size and weight of the segments will pose challenges for transportation and handling.**



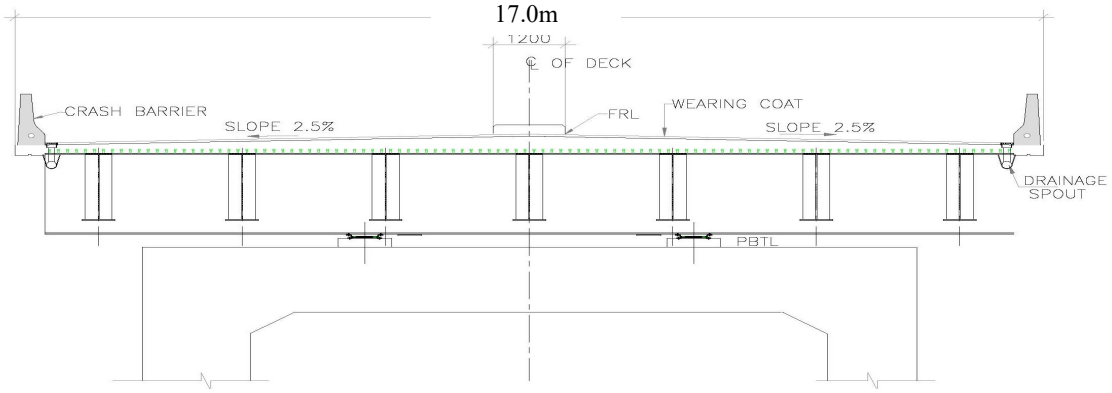
7.3.2 Option – II: Spine and Wing

- Deck Width: The design allows for a very wide deck from a narrow central spine, which is useful for maximizing roadway space.
- Phased Construction: The spine can be constructed first, with the wings added later, which can help with project phasing.
- Aesthetics: The wide, open-deck appearance can be more visually appealing in certain contexts.
- Complexity: The connections between the spine and the wings can be structurally complex and require precise detailing.
- Material Use: **This method often uses a combination of cast-in-situ and precast elements, which can add to the on-site complexity**.



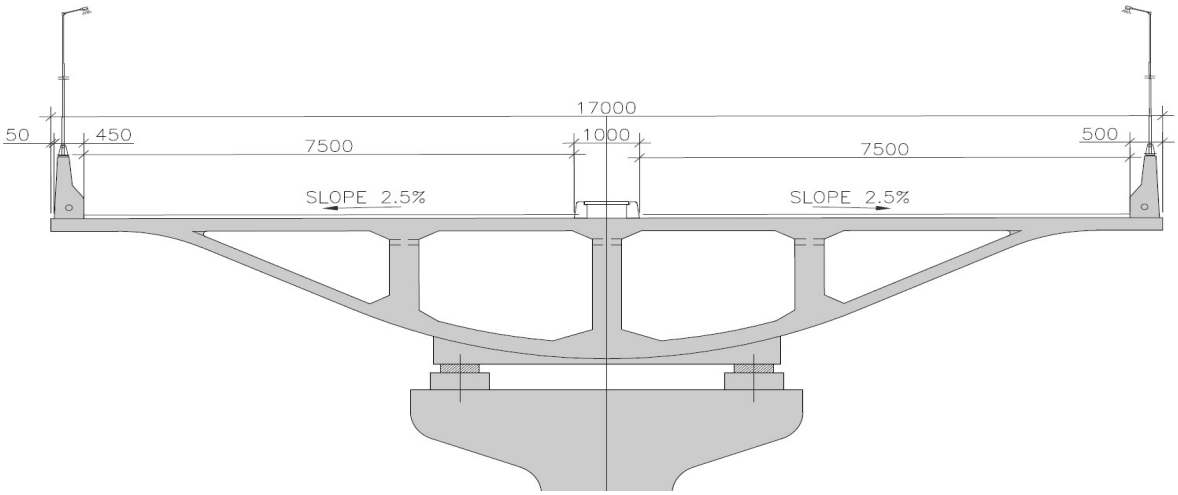
7.3.3 Option – III: Composite Steel Girder

- Weight: Steel is lighter than concrete, which can reduce the size and cost of foundations and supporting piers.
- Long Spans: This is an excellent option for long spans where the self-weight of a concrete structure would be too high.
- Fabrication: Steel girders are fabricated off-site, which allows for faster on-site erection.
- Maintenance: Steel requires regular inspection and maintenance, such as painting, inspection of joints to prevent corrosion, adding to long-term costs.
- Cost: Steel is a more expensive material than concrete, which can increase the initial project cost.



7.3.4 Option – IV: Composite Fish Belly / U-Trough UHPFRC+HPC Slab

- Structural Efficiency: The use of Ultra-High Performance Fiber Reinforced Concrete (UHPFRC) allows for a thinner and lighter structure, reducing dead load on foundations.
- Durability: UHPFRC is extremely dense and resistant to deterioration from chemical attacks, leading to minimal maintenance.
- Construction Speed: The precast U-trough segments can be assembled very quickly, drastically shortening the construction schedule.
- Ease of Transportation: The lightweight nature of the UHPFRC sections makes them easier and more economical to transport from the casting yard to the construction site. This simplifies logistics and reduces costs associated with Transportation.
- Cost-Effectiveness: While the initial cost of UHPFRC may be comparatively higher compared to first 2 options, the reduced material usage, faster construction, and minimal maintenance lead to a lower total life-cycle cost, making it the preferred option.



7.3.5 Superstructure Comparative Study of Cost

Item of Work	Unit	Option -1 (30m Segmental Box)			Option -2 (30m Spin & Wing)		
		Quantity	Rate	Cost	Quantity	Rate	Cost
M50 Concrete	Cum	398.09	14,200.00	5,652,878.00	368	14,200.00	5,225,600.00
UHPFRC -M150	Cum						-
Untensioned Steel	MT	90.2	95,325.00	8,598,315.00	73.83	95,325.00	7,037,844.75
Prestressing Steel	MT	16.5	257,639.00	4,251,043.50	27.6	257,639.00	7,110,836.40
Structural Steel	MT						
				18,502,236.50			19,374,281.15
			Rate/ Sqm	36,278.90		Rate/ Sqm	37,988.79

Item of Work	Unit	Option -3 (45m Structural Steel)			Option -4 (50m UHPFRC)		
		Quantity	Rate	Cost	Quantity	Rate	Cost
M50 Concrete	Cum	194	14,200.00	2,754,800.00	230	7,546.00	1,735,580.00
UHPFRC -M150	Cum				250	97,451.00	24,362,750.00
Untensioned Steel	MT	30	95,325.00	2,859,750.00	55	95,325.00	5,242,875.00
Prestressing Steel	MT				40	257,639.00	10,305,560.00
Structural Steel	MT	310	171,080.00	53,034,800.00			
				58,649,350.00			41,646,765.00
			Rate/ Sqm	76,665.82		Rate/ Sqm	48,996.19

7.3.6 Preferred Option:

Considering minimum inconvenience to grade level traffic during construction, quality of construction, low maintenance requirement, speed of construction, aesthetics**, "Fish Belly and U-Trough UHPFRC" construction (i.e., Option –IV) is the preferred option.**

From the Above comparison, comparing direct cost, of construction option 1 and 2 is having least cost. Option-3 is cost prohibitive to adopt for the entire corridor. Option-4 with 50m UHPFRC composite super structure the cost of super structure is about 28% higher compared to option-2. However, there will be reduction in cost of sub structure Super structure with UHPFRC composite i.e., **Fish belly &**

U- trough with UHPFRC and top slab with M50 is recommended with following advantages.

1**. Sleek sections and elegant appearance of structure.**

2. Significant reduction in the weight and hence suitable for long spans.

3. Ensures high quality of concrete as it is produced with less w/c ratio in a controlled environment.

4. Attains early strength and hence faster construction cycle which reduces construction period.

5. Life cycle cost is less as the maintenance requirement for UHPFRC is negligible

6. Significant reduction of Shrinkage and creep.

Though cost of construction for Composite steel super structure is more, composite structural steel super structure is proposed for elevated rotaries, rotary adjacent spans, at few critical locations keeping ease of construction point of view.

- For Super structure of rotary and adjacent spans of rotary, 60m obligatory span at Town hall, Composite steel + RCC deck is considered for ease of construction.
- For sub structure of rotary and rotary adjacent spans at Hudson circle, suitably planned portal frames are proposed with out affecting the Grade level movement of traffic.

7.3.7 Sub structure and Foundation

Sub structure is proposed with RCC single rectangular piers for main corridor and approaches. Rotary Portal piers with pier beam is proposed as single pier is not feasible with the presence traffic movement at grade. The piers are located at edge of carriage way at rotary.

For piles Bored cast in situ Piles of 1350/1200mm dia is adopted.

For sub structure of rotary and rotary adjacent spans at Hudson circle, suitably planned portal frames are proposed with out affecting the Grade level movement of traffic.

7.3.8 Bearings & Expansion joints

Mechanical Bearings, spherical bearings are considered and Slab seal expansion joints are used.

CHAPTER- 8 – TRAFFIC DIVERSION AND MANAGEMENT PLAN

8.1. General

The existing corridor over which elevated road is proposed is a vital connection to many important locations of the city.

The major roads around this corridor are K.R. Road, N.R. Road and Kengal Hanumanthaiah Road, SJP Road, Sheshadri Road, in view of heavy traffic on the major roads around the corridor and connectively of South Bangalore towards K.G. Road and M.G Road, traffic diversion from the corridor under study is not feasible, hence only "Traffic Management" is to be planned, allowing the vehicle movement along the corridor.

Traffic management is done under following phases –

To minimise the least hinderance to the traffic movement following measures has been taken while preparing the proposals –

- Precast technology is adopted which will be erected using Overhead launching girders/underslung system.
- Existing service roads will be resurfaced and new service roads for construction purpose will be formed
- Constructing the new service roads wherever there are no existing service roads.
- Barricading the construction site.

- Deployment of Flagmen.
- Proper signages at the working area indicating diversions and other cautionary sign boards.

Traffic management to be followed along existing road.

Traffic management may be under following guidelines during various phases –

8.2. Traffic Management during Construction.

8.2.1 Phase – I: Widening and reconstruction of existing carriage way and construction of foundation.

Hard barricading and safety measures are proposed in the construction area, allowing the traffic movement along the existing carriage way.

8.2.2 Phase – II: Construction of Viaduct for Main Carriageway and Loops is planned during this phase.

Hard barricading and safety measures are proposed in the construction area, allowing the traffic movement on either side over existing and extended carriage way.

8.2.3 Phase – III: Construction of Rotary is envisaged during this phase.

Erecting of pre-fabricated structural steel box girder at Hudson circle. Rotary span with suitably designed vent ways for allowing traffic movement. Barricading and safety measures to be implemented.

The above scheme of traffic management is tentative which is to be approved by the traffic police and the responsibility of approval and implementation rests with construction agency.

CHAPTER- 9 – LEGAL ASSESSMENT

9.1. Land Acquisition

The Project Area lies in Well Developed Residential as well as in Commercial Area 413 Sqm of private land needs to be acquired under for the proposed Elevated Road from Minerva Circle to Hudson Circle. Details of Land Acquisition are given in Drawing No: VC/ B-Smile/JCR/DPR/03.

9.2. Enforcement Measures

B-SMILE has planned to take Precautionary Measures during the Construction Phase to enforce Traffic Diversion and minimizing the effects of various Pollutions. Through the Institutional Framework suggested, B-SMILE will coordinate with the Traffic Police, BMTC and Utility Operators like BESCOM, BWSSB for the Shifting of Existing Utility Lines, which are going to obstruct the Execution of the Project. Since BSMILE is the Obligatory Provider of Citizen Services in the City, it has powers by statue to require other Government and Non-Government Agencies to implement Plans in Public Interest. B-SMILE has also notified the List of Underpasses and Flyovers that it proposes to construct and thus it is making the Residents and Commercial Establishments aware of the possible disturbances that could emerge on account of the Implementation of the Projects.

Present Proposal crosses the proposed phase 3 A metro line at NR Road and going towards K.R. Circle along Nripathunga road. We understand the BMRCL facility is underground, and it will be at around 14m below ground level. It may be with twin cell tunnel with overall 15m width including 2m clearance between 2 cells. Our arrangement is not fall on the metro line.

Other stake holders along the corridor whose utilities are crossing the present proposal viz., KPTCL, BESCOM, BSNL , etc., are informed regarding the project with a letter and set of project drawings and costing towards necessary utility shifting are accounted in the DPR

CHAPTER- 10 – RISK ASSESSMENT

10.1. General

In a Road Project there are considerable risks involved during the implementation of the project. The risks during the operation phase are minimal and restricted to over use of the road (against Design Assumptions) by heavier vehicles and damage to road surface by accidents and by vehicles carrying overload. In the current elevated road projects undertaken by B-SMILE, the time frame for completion varies between 18 to 24 months after mobilization of site resources. The major risk relates to buy in of the project from all stakeholders, especially those affected by the construction itself. These are residential and commercial establishments who are close to the construction site. They are exposed to noise pollution, dust pollution and inconvenience caused due to inability to use their vehicles on account of temporary closure of the roads.

Internal Risks come mainly from three sources: the Project, the Organizations Involved and the Relationships among Partners. Most projects suffer at least temporarily from a deficient project structure: many are launched even though objectives are not clear, a business case had not been completed, and milestones were only vaguely defined, if defined at all. These instances of lack of or inadequacy in definition of scope occur due to pressure to complete the planning stage and to go ahead with the construction early. On the organizational side, lack of project control mechanisms is the factor that most impede many projects. Finally, risks

associated with the relationships among partners have been the major source of concern present in all projects, lack of definition of role and responsibility as the most important problem for project implementation.

The Risks associated with the road projects fall into four categories.

- Multiple Stakeholder Coordination Risk during execution of work (very critical in the road projects of Bangalore).
- Project Risk (Clarity in Scope, Clarity in Role and Responsibility).
- Acquisition of Land and Removal of Encroachments while Widening the Drains.
- Shifting of Utilities – Perfect Coordination among the Concerned Stakeholders and the Contractors.

10.2. Stakeholders

The Stakeholders involved in the Bangalore Road Projects are:

- B-SMILE.
- Utility Companies.
- Traffic Police.
- Public Works Department.
- Residents' Association.
- Shop Owners' Association.
- Pollution Control Board.

10.3. Role of Traffic Police

Coordination with the Traffic Police, Liaison with Residents and Shop Owners' Association is a pre requisite before commencing the Construction Phase. Traffic Police will have to plan for Diversions/management of traffic, Construction of Temporary Structures, and Regulation of Traffic during Peak Hours with Extra Resources, etc. Communication through Media and Door – to – Door Campaign in the affected areas are proposed to ensure smooth Construction Phase.

Traffic Police will also have to develop alternate routing for the BMTC Buses that ply in the roads proposed for revamping. They need to mark the zones near the Construction Site as 'No Parking' and allocate Routes and Space for the Vehicles engaged in the Construction Work.

10.4. Shifting of Utilities

In Bangalore Road Network, the common Utilities that are encountered during the revamping or widening are

- Sewer and Drainage Lines.
- Water Supply Lines.
- Electricity Lines and Structures (Mounted Transformers).
- Telecommunication Lines and Structures.
- Street Lights.
- Parking Signs.
- Post Boxes.
- Signals.

The utilities are to be shifted in coordination with the Concerned Departments. The key is in sending them advance communication and obtaining their sign off for proposed shifting well ahead of the Construction Phase. Underground utilities are the main concern and pose a major challenge that will need the commitment and cooperation of all the associated Departments. Shifting of underground utilities are to be executed in coordination with BWSSB, KPTCL, BESCOM, BSNL and other private Telecom Operators like Bharti, Tata, Reliance, etc., which have led OFC cables along the existing roads.

10.5 Risk Management

Risk	Stakeholders	Severity of Risk	Solution
Acquisition of Land	B-SMILE, Government of Karnataka	Medium	A Combination of Enforcement and Rehabilitation measures is required to notify the affected people and provide Alternate Arrangements for living. In the case of road projects the instances are minimal.
Removal of Encroachments	B-SMILE, BDA, Government of Karnataka	Medium	Legislation followed by proper Enforcement; affected people to be considered for Housing under Basic Services to Urban Poor Plan.
Traffic Management	B-SMILE, Contractors, Traffic Police	High	A Well-Coordinated Traffic Management Plan with clearly Defined Roles is required. Participation of Residents and Shop Owners at the Formulation Stage is also recommended.
Risk	**Stakeholders**	**Severity of Risk**	**Solution**
Accident Free	B-SMILE, Contractors, Traffic Police	Medium	Proper Deployment of Resource at critical periods of time and Inspection of Vulnerable Structures and Traffic Diversion Routes.
Dumping of Construction Debris	B-SMILE, Contractors	Medium	Storage Space shall be allocated along the Construction Site, Instructions for Clearing and

			Dumping the Debris Outside the Construction Sites shall be issued.
Protection of Pipe line	B- SMILE, BWSSB and Contractors	Medium	The water pipe line of larger diameter along the pipe line corridor shall be protected by MS encasement at pile and pile cap location
Compound wall	B-SMILE, Contractors	Low	Wherever construction is in close proximity to the structure and in forest area compound wall to be constructed

10.6 Internal Risks associated with Road Projects in Bangalore City with Suggested Measures to Address the Risks

Risks Associated with the Project itself	***Characteristics of Clients / Users of the Service:*** Resistance to Change, Lack of Involvement, Inadequate Education Level, Difficulties in Communicating, Unrealistic Expectations. (To overcome B-SMILE is seeking Citizen Participation through Ward Committees and others for Buy In the Project and Speedy Implementation). ***Scope of the Project:*** Universality or Specificity of the Service, Number of Partners Involved, Number of Clients, Size of Budget. (Contract Documentation being revamped to define the Role and Responsibility very clearly emphasizing on the need to communicate with the Stakeholders at the Critical Times). ***Complexity of the Project:*** Especially Organizational and Technological Complexity. (Consultant would evaluate various assumptions made in the Design and Detailed Engineering while executing the Project and provide Feedback to B-SMILE). ***Definition and Structure of the Project:*** Unclear Objectives, Ill Defined Specifications and Functional Requirements, Changes in the Scope or the Reach of the Project, Difficulties in Integrating Data or Processes. (Flexibility to Accommodate Changes by the Contractors included in the Contract Documentation).
Organizational Risks	***Lack of Resources:*** *U*ncertainty of Funding, Inadequate Resources, Lack of Expertise in Complex Resource Management (these may not be critical under State Govt Funding). ***Project Team Competencies:*** Lack of Experience, Expertise, Stability and Communication Skills. (It is proposed to establish a PMU for Road Projects within B-SMILE with Requisite Skills and Experience). ***Management Strategy:*** Inadequate or Inappropriate

	Organizational Support and Control, Absence of a Champion, Lack of Leadership, Unavailability of Tested Management Tools and Processes. (Inter Institutional Committee proposed to deal with Policy Level Decisions including Release of Funds from the State Government). ***Technological Know How:*** Absence of an Adequate Technological Infrastructure and of In-House Technological Competencies. (Competencies being Upgraded as well as Latest Construction Practices followed in Road Construction, Material Handling and Disposal of Construction Debris).
Relationship Risks	***Form of Collaboration:*** Inadequate or Inappropriate type of Agreement, Misunderstandings regarding the Content of the Agreement, Inappropriate Selection of Partners, etc. (All Contractual Frameworks to define the Role, Responsibility and Liability of Various Parties clearly; Contractors to be provided with Opportunity to seek Clarification before Accepting the Work). ***Collaborative Process:*** Problems occurring with Coordination, Communications, Inertia, Dependency, Mistrust, Lack of Consensus or Involvement (Change Management Process proposed to be handled by the PMU).

CHAPTER- 11 – ENVIRONMENTAL AND SOCIAL IMPACTS

11.1. General

In any major developmental initiative aimed at promoting the interests of the community or the State / Country, the Associated Environmental Impacts – whether of a Short Term or Long-Term Nature, likely to affect the Environment, Ecology and Health of the Community, need to be seriously examined, before embarking on the proposed project. The Primary Objectives of the Environmental Impact Assessment (EIA) are to evaluate the existing pre operational baseline environmental status at the proposed project site by field studies and data collection, and then carry out an Objective Assessment of the various impacts on the Environment as a result of the proposed activities.

As “Construction of Grade Separator (Flyover) along JC Road from Minerva Junction to Hudson Circle” is one of the major Metropolitan Infrastructure Projects for Bangalore, it is imperative to conduct an Environmental Impact Assessment (EIA) to quantify the Benefits accrued to the Community as a result of the Project, while at the same time analyzing carefully the Impact Aspects due to the Project itself, during Construction and Operation Phase Cycles. As these Data are crucial for the Planning and Successful Implementation of the Project, Various Data (such as Nos. of Tree Cutting, Extent of Air and Noise Pollution, etc.) have been collected from extensive site studies in accordance with well-established Standard Procedures.

The existing road infrastructure on JC Road have deteriorated remarkably as a result of lack of investment and multifield increase in traffic volume and have to be upgraded to higher service levels in order to reduce transport cost in support of Socio-Economic Development.

Discussions held with Government and Non-Governmental Organizations and a Detailed Site Assessment have been carried out to provide the basic background for Impact Identification and Assessment. A Scoping Exercise has also been carried out at the Pre-Construction Stage to identify and highlight the Key Issues and Impacts likely to occur during the Construction, Operations and Maintenance Phases of the Project, as well as to identify those Impacts which could, but are unlikely to occur. Practical and Cost-Effective Benefit Enhancement and Mitigation Measures have been identified and outlined, taking into account alternative approaches that are appropriate to the situation. A Management and Monitoring Plan was developed to provide a sound basis for ensuring that the specified benefit enhancement and mitigation measures are fully adopted.

For Planning and Implementation of “Flyover”, we have given due attention to the Environmental and Social Issues. The Various Issues addressed under this Section are as follows.

11.2. Environmental Impact

11.2.1. Green Cover

Bangalore City – with its rich flora and abundant green cover and being host to Lalbagh and Cubbon Park, which are renowned botanical gardens, is rightly called the "Garden City of India". Bangalore City bagged the Central Government sponsored "Indira Priyadarshini Vruksha Mitra" Award in the late 1980s in recognition of its extensive green cover. But today, lung space is shrinking in the city and core areas have lost green cover with increase in concrete structures. As a part of this project, to acquire obstruction free area, 60 trees to be cut in the project area. Considering the Benefits of the Project and the Compensatory Afforestation Plan envisaged, it has been observed with management plans consisting of planting of trees in the ratio of 1:2, proactive afforestation for green cover and development of green ribbon in and around the project area, it will be abundantly compensating the green cover. for number of trees to be chopped, afforestation and translocation of trees have been planned.

11.1.2 Air Pollution

Air Pollution level will go up during the Construction Stage due to operation of construction yards, material transport on trucks and due to heavy earth moving machinery exhaust emissions (e. g. SPM, RSPM, NO_x, SO_x, CO, etc.) from the construction sites. These are not permanent in nature, but minor, temporary and mitigatable. In the post construction scenario, the General Level of Air Pollution in the project area will be significantly less than the current level due to improved movement of vehicular traffic and removal of

idling time and thus this project ensures better environment. The Consultant has collected data regarding existing Air Quality in and around the project area and is given **Table 11.1 to 11.3.** All vehicles delivering materials to the site will be covered to avoid spillage of materials. All existing highways / roads used by vehicles of the Contractor, or any Sub Contractor or Suppliers of Materials or Plant and similarly Roads, which are part of the Works, will be kept clean and clear of all dust / mud or other extraneous materials dropped by such vehicles. The unloading of materials at construction sites close to settlements will be restricted to night time only. Vehicles and Equipment will be fitted with Exhaust Silencers. During routine service operations, the Effectiveness of Exhaust Silencers will be checked and if found defective will be replaced. Unpaved Haul Roads near / passing through residential and commercial areas to be watered thrice a day. Trucks carrying construction material are to be adequately covered. All Earthworks will be protected in a manner acceptable to the Engineer (such as Barricading the Construction Site) to minimize Dust Nuisance in the surrounding area. The Contractor will take every precaution to reduce the Level of Dust along Construction Sites involving Earthworks, by frequent application of water.

Table 11.1
At Minerva Junction

Ambient Air Quality Monitoring

Type of Monitoring **Ambient Air Quality**
Duration of Sampling **24 hrs.**
Instrument used for Monitoring **Respirable Dust Sampler APM 460 & 411.**

Descriptions	**Value in µg / m^3**	
	Existing	Permissible
Respirable Particulate Matter	**166.0**	120.0
Suspended Particulate Matter	**422.0**	360.0
Oxides of Sulphur	15.9	80.0
Oxides of Nitrogen	40.3	80.0

Table 11.2
At Town Hall Junction

Ambient Air Quality Monitoring

Type of Monitoring **Ambient Air Quality**
Duration of Sampling **24 hrs.**
Instrument used for Monitoring **Respirable Dust Sampler APM 460 & 411.**

Descriptions	**Value in µg / m^3**	
	Existing	Permissible
Respirable Particulate Matter	**166.0**	120.0
Suspended Particulate Matter	**422.0**	360.0
Oxides of Sulphur	15.9	80.0
Oxides of Nitrogen	40.3	80.0

Table 11.3
At Hudson Circle
Ambient Air Quality Monitoring

Type of Monitoring **Ambient Air Quality**
Duration of Sampling **24 hrs.**
Instrument used for Monitoring **Respirable Dust Sampler APM 460 & 411.**

Descriptions	**Value in µg / m^3**	
	Existing	Permissible
Respirable Particulate Matter	**173.0**	120.0
Suspended Particulate Matter	**424.0**	360.0
Oxides of Sulphur	15.9	80.0
Oxides of Nitrogen	40.3	80.0

11.1.3 Water and Soil pollution

The Surface and Underground Water and Soil Pollution Aspects are not likely to be greatly influenced, unlike Air Pollution Quality by the Construction of Elevated Corridor along JC Road from Minerva Junction to Hudson Circle, However, there could be Indirect Impact on the Water and Soil Components in the long run.

As the Project Activities need substantial water quantities for construction processing, dust proofing, cleaning of vehicles and batch mixing, etc. there could be considerable demands on water resources available. Necessary arrangements and contingency plans with BWSSB and Arrangement for Supply of Recycled Water should be made to meet the Water Demands, without in anyway affecting the city's normal water supply demands.

With the proposal of UHPFRC (Ultra High Performance Fibre reinforced concrete), HPC (High Performance Concrete) and Composite steel girders, water requirement is minimised. With the proposal of Pre cast UHPFRC, where curing will be with steam curing, recycling of the water can be made there by reduction in the water requirement.

All the Proposed Project Components will be in Well Developed Areas of the City with Distinct Land Usage Patterns ranging from Residential to Commercial Activities under Well Established Conditions. As Construction Activities are primarily land based, many Impacts can be identified in the Soil Component in the Proposed Area. Excavation Activity will produce a lot of rubble from excavated soil, needing disposal. The excavated soil / debris will be disposed by covered trucks to avoid Dust Nuisance in the Project and Surrounding Areas. Debris generated due to the dismantling of the existing pavement structure shall be suitably reused in the Proposed Construction, subject to the Availability of the Material and the Approval of Project Engineer. The Contractor shall suitably dispose of Unutilized Debris Material; either through filling up of Borrows Areas created for the Project or at Pre-Designated Dump Locations, subject to the Approval of the Project Engineer. Debris generated from different Construction Activities shall be disposed of in such a way that it does not flow into the Surface Water Bodies or form Mud Puddles in the area.

As the concrete used for sub structure is from RMC, water required only for curing purpose only. For Curing purpose, potable water shall be used and percolating water will not pollute the ground water table.

11.1.4 Noise Pollution

As the Project involves significant uses of Heavy Machineries, Traffic Diversion, etc. hence Noise Concern will be a major issue during Construction Phase. But the Post Construction Scenario ensures a Better Environment in the Project Area, as the General Level of Noise Pollution in the Project Area will be significantly less than the Current Level due to Improvement in the Movement in Vehicular Traffic and Removal of Idling Time. The Consultant has collected existing Noise Level Data in and around the Project Area and is given Table 11.4. to 11.6 To mitigate the Noise Impact, Direct Technical Remedies including Low Noise Road Surface, Road Covers and Roadside Noise Barriers will be provided. Noise Limits for Construction Equipment used in this Project (measured at one metre from the edge of the equipment in free field) such as Compactors, Rollers, Front Loaders, Concrete Mixers, Cranes (movable), Vibrators and Saws will not exceed 75 dB (A), as specified in the Environment (Protection) Rules, 1986. Notwithstanding any other Conditions of Contract, Noise Level from any Item of Plant (s) must comply with the Relevant Legislation for Levels of Noise Emission. The Contractor will ensure that the AAQ Concentrations as these Construction Sites are within the Acceptable Limits of Industrial Uses in case of Hot Mix Plants and Crushers and Residential Uses around Construction Camps. Noisy Construction Operations in Residential and Sensitive Areas (Hospitals, Schools and Religious Places) should be restricted between 0730 hrs. and 1800 hrs. Preventive Maintenance of Construction Equipment and Vehicles would be done to meet Emission Standards and to keep them with Low Noise. Earplugs will be provided to

Operators of Heavy Machinery and Workers in near vicinity. Material Transport should be uniformly distributed during nights to minimize Noise Impacts. Noise barriers will be proposed at required locations in discussion with clients. Mainly near the government school near RV road at Minerva junction.

Part of the Costs, particularly the Implementation of Environmental Measures is included in the Unit Rates for the Works and is responsibility of the Contractor.

Table 11.4

At Minerva Junction

Existing Noise Level Monitoring

Instrument used for Monitoring **Sound Level Meter Lorton SL – 4001**

Permissible Limits **75 dB (A) – Day Time**

70 dB (A) – Night Time

Sl. No.	Time Interval	Noise Level in dB (A)
1	0600 hrs. to 0700 hrs.	71.9
2	0700 hrs. to 0800 hrs.	72.3
3	0800 hrs. to 0900 hrs.	72.9
4	0900 hrs. to 1000hrs.	73.5
5	1000 hrs. to 1100 hrs.	73.7
6	1100 hrs. to 1200 hrs.	72.1
7	1200 hrs. to 1300 hrs.	71.1
8	1300 hrs. to 1400	71.6

		hrs.	
	9	1400 hrs. to 1500 hrs.	71.5
	10	1500 hrs. to 1600 hrs.	71.4
	11	1600 hrs. to 1700 hrs.	72.1
	12	1700 hrs. to 1800 hrs.	72.4
	13	1800 hrs. to 1900 hrs.	73.4
	14	1900 hrs. to 2000 hrs.	73.2
	15	**2000 hrs. to 2100 hrs.**	**72.3**
	16	**2100 hrs. to 2200 hrs.**	**72.1**

Table 11.5
At Town Hall Junction

Existing Noise Level Monitoring

Instrument used for Monitoring Sound Level Meter Lorton SL – 4001

Permissible Limits 75 dB (A) – Day Time

70 dB (A) – Night Time

Sl. No.	Time Interval	Noise Level in dB (A)
1	0600 hrs. to 0700 hrs.	71.9
2	0700 hrs. to 0800 hrs.	72.3
3	0800 hrs. to 0900 hrs.	72.9
4	0900 hrs. to 1000hrs.	73.5
5	1000 hrs. to 1100 hrs.	73.7
6	1100 hrs. to 1200 hrs.	72.1
7	1200 hrs. to 1300 hrs.	71.1
8	1300 hrs. to 1400 hrs.	71.6
9	1400 hrs. to 1500 hrs.	71.5
10	1500 hrs. to 1600 hrs.	71.4
11	1600 hrs. to 1700 hrs.	72.1
12	1700 hrs. to 1800 hrs.	72.4
13	1800 hrs. to 1900 hrs.	73.4
14	1900 hrs. to 2000 hrs.	73.2

15	**2000 hrs. to 2100 hrs.**	**72.3**
16	**2100 hrs. to 2200 hrs.**	**72.1**

Table 11.6

At Hudson Circle

Existing Noise Level Monitoring

Instrument used for Monitoring **Sound Level Meter Lorton SL – 4001**

Permissible Limits **75 dB (A) – Day Time**

70 dB (A) – Night Time

Sl. No.	Time Interval	Noise Level in dB (A)
1	0600 hrs. to 0700 hrs.	71.9
2	0700 hrs. to 0800 hrs.	72.3
3	0800 hrs. to 0900 hrs.	72.9
4	0900 hrs. to 1000hrs.	73.5
5	1000 hrs. to 1100 hrs.	73.7
6	1100 hrs. to 1200	72.1

		hrs.	
	7	1200 hrs. to 1300 hrs.	71.1
	8	1300 hrs. to 1400 hrs.	71.6
	9	1400 hrs. to 1500 hrs.	71.5
	10	1500 hrs. to 1600 hrs.	71.4
	11	1600 hrs. to 1700 hrs.	72.1
	12	1700 hrs. to 1800 hrs.	72.4
	13	1800 hrs. to 1900 hrs.	73.4
	14	1900 hrs. to 2000 hrs.	73.2
	15	**2000 hrs. to 2100 hrs.**	**72.3**
	16	**2100 hrs. to 2200 hrs.**	**72.1**

11.1.5 Social Impact

The Direct and Indirect Job Opportunities that will be provided by the Project can be considered as a Positive Aspect. The Local People will be directly employed to work at the Construction Sites and others will be employed in Sectors of the Economy, which have been developed by the Road such as the Service Sectors. Some individuals may gain skills that can be applied in other Road Construction Projects.

Contract Documentation will be crafted in such a way that the Construction Work does not cause undue Inconvenience to Residents, especially the Sick and Old People. Removal of Construction Debris promptly from the Site falls within the Scope of Work of the Contractor. Asphalting, the Major Work, involved in the Road Construction would invariably be carried out during the nights with Proper Inspection Team supervising the Process.

The table below summarizes the Negative Environmental and Social Impacts and Mitigation / Benefit Enhancement Measures for the Negative Impacts, as well as the responsible body to implement the measures.

Type of Impact	Mitigation Measure	Responsible Body for Implementation
Impact on Settlement	Minimize the Risk at the Road particularly in a Dense Settlement Area.	Consultant and Contractor.
	Allow Affected Persons to Salvage Building Materials and other Assets.	B-SMILE and Contractor.
	Pay Compensation and Resettle the Affected People.	B-SMILE.
Impact on Health	Do not Induce Water Related Diseases by creating Temporary and Permanent Water Holding Areas, which favour Mosquitoes.	B-SMILE and Contractor.

	Minimize Dust Emission by Watering the Road during Construction.	Contractor.
	Put Visible and Appropriate Warning Signs on the Road during Construction.	Contractor.
Impact on Existing Infrastructure	Relocate Power Lines, Telephone Lines and Water Points before Commencing of the Road Construction and in few cases during the Construction Phase.	Utility Companies and Contractor.
Impact on Cultural, Religious and Archaeological Resources	Design Roads to avoid such Sensitive Places.	Design Consultant.
Road Safety during Construction and Operation Phase	Install Road Safety Signs at all Accident Prone Spots as Installation / Erection of Safety Signs.	Traffic Police / Contractor.
	Provide Traffic Awareness.	Contractor in collaboration with Traffic Police of the Area and Local NGO.
	Use Clear, Properly Labelled and Meaningful Traffic Signs and Speed Limits, especially at Pedestrian Road Crossing.	Contractor in collaboration with Traffic Police of the Area.
	Assign Traffic Personnel to regulate the Passage of Construction Vehicles (carrying debris as well).	Contractor in collaboration with Traffic Police of the Area.
	Construct Half of the Road while the other is used for Traffic where feasible.	B-SMILE and Contractor.
Social Impact from Migrant Workers	Construction Workers will be given Health Awareness.	NGOs in collaboration with the Contractor.
	Avoid accommodating Labour Force in or directly adjacent to Construction Sites.	Contractor.

	Recruit Work Force from the Local Community giving more chances to Women.	B-SMILE and Contractor.

11.1.6 Requirements for Prior Environmental Clearance:

As per EIA notification 2006, a prior environmental clearance is required for highway projects as mentioned in cl 2 and schedule to the clause 2. The extract of the same is presented below-

2.0 Requirement of prior Environmental clearance (EC): Following projects/Activities shall require prior environmental clearance from concerned regulatory authority, which shall hereinafter referred to be as the central government in the ministry of Environmental and forests falling under category "A'" in the schedule and state level, The state Environmental Impact assessment Authority (SEIAA) for matters falling under category "B" in the said schedule.

Schedule: List of Projects OR Activities requiring Prior Environmental clearance

Project/Activity	Category with Threshold Limit		Condition if any
	A	B	
7(f) (Highways)	i. New National Highways and ii. Expansion of National highways greater than 30km involving additional right of way greater than 20m involving land acquisition and passing through more than one state	i. New State Highways and ii. Expansion of National highways/State highways greater than 30km involving additional right of way greater than 20m involving land acquisition.	General Condition shall apply

Since the project under this Detailed Project report doesn't fall under the category of A or B as per the notification/schedule the project does not require Prior Environmental clearance as per the notification.

CHAPTER- 12 –PARTICIPATION OF BENEFICIARIES

- Any Infrastructure Development Activities of B-SMILE are planned and implemented through Community Participation Process. Local Government Institutions at various levels are involved in the Implementation of Projects. Moreover, NGOs are involved to assist B-SMILE in Social Mobilization Aspects for Planning and Implementation of the Project. As a part of Participatory Development, Beneficiary Groups and User Committees, such as Labour Contracting Society, Market Management Committee, Road User's Committee, Water Management Committee, etc. have been consulted under various Projects of B-SMILE. Involvements of the Private Sector, Local Government Institutions, NGO and Beneficiary Groups have significantly contributed to Smooth Planning, Implementation and Operation / Maintenance of Infrastructure Development Schemes of B-SMILE at the Local Level. Consultation with various Stakeholders has been an Integral Part of Project Formulation Phase. People have been interviewed along the route, including Elders and Elected Members of the Community; have given a positive reaction to Road Improvement. The Project Junction is very important in terms of connecting the National Highways. Social Acceptability of the Project Junction is very high.

- This Project will have many Positive Impacts on Beneficiary Livelihoods and in the Potential Economic Expansion of the Region. Beneficiaries of this Project include Bangalore Metropolitan Transport Corporation (BMTC)

Authority, Commuters using this stretch of road, Local People in and around of the Project Area.

- Public Opinion with regard to public projects cannot be ignored. It plays a very important role in the decision-making process. Given the chaotic road traffic on JC Road, Public Opinion Survey is conducted on the basis of a sample of cross section of intelligentsia drawn from Lawyers, Doctors, Engineers, Academicians, Journalists, etc. the Opinion Makers in Urban Situation upon finalisation of GAD after the approval TAC and B-SMILE. Interactive Sessions with NGOs and Various Members of the City Public also formed part of the Exercise in this Direction.

- Prior Information to the Public, before the Start of the Work, regarding the Project will be given through Paper Notification.

- Boards, comprising Important Data regarding the Project (such as Project Name, Name of the Agency executing the Work, Name of Local Government Body taken up the Project, Date of Commencement of the Project, Projected Date to Complete the Work, etc.) for notifying people will be displayed at the major junctions in and around the project area.

- Adequate actions to direct and regulate traffic shall be taken in consultation with B-SMILE / Traffic Police to prevent jamming roads during Construction Period. While planning alternative routes, care to be taken to minimize congestion and negative impacts at sensitive receptors such as Schools and

Hospitals. Traffic Controls and Diversions marked with Signs and Lights and Other Measures (flags) should be provided. Prior to creating Diversions and Detours, the citizens will be consulted well in advance through Citizen's Meetings. It should be an informed decision taken through Public Participation. The Temporary Traffic Detour will be cleaned regularly.

- Another significant aspect of the Construction of Elevated Corridor from Hudson Circle to Minerva Junction would be its Dislocation Effect on the existing public utilities like Electrical System Network (including Street Lighting), Sewerage Lines and Water Supply Network, etc. As the Public Utility Network are very vital for a normal functioning of an Urban Metropolis, a Detailed Survey of Existing Utilities and their Diversion or Reinstallation on a temporary or permanent basis should be planned in a proactive manner and organized with minimum loss of time and inconvenience to the community. Prior Information through Paper Notification will be given to the affected area people before shifting any Utilities.

- The Project is judged to be environmentally and socially acceptable.

CHAPTER- 13 – CONCLUSIONS AND RECOMMENDATION.

13.1 CONCLUSIONS

The construction of Elevated Corridor from Hudson Circle to Minerva Junction along JC Road and loop flyover from existing Bala Gangadhara Nath Swamiji flyover to Townhall and Elevated Corridors from Sangolli Rayanna circle (Anand Rao Flyover) to Nrupathung road (KR Circle), coupled with the traffic management will have the following additional benefits:

- Reduced junction delays and Vehicular Pollution
- Reduction in idle fuel consumption
- Improved level of service at the Junction
- Substantial savings in travel time of Road users
- Reduces the number of conflicts.

13.2 PROPOSAL

- 4 Lane bi-directional elevated corridor from Hudson Circle to Minerva junction along JC Road and NR road.
- 2- lane up ramp from VV puram Diagonal Road,
- Up ramp from RV Road at Minerva Junction.
- Unidirectional 2-lane arm from Existing BGS flyover to connecting proposed elevated Road at Town Hall.
- Elevated rotary at Hudson Circle for circulation of traffic to various directions without any hindrance.
- 2- lane entry arms at Hudson circle from Nrupathunga Road,

Rajaramohan Roy Road.

- 2- lane Exit arms at Hudson circle towards KG Road, Kastur ba Road.
- Grade level junction improvement at lalbagj west gate.
- 2-lane Elevated Unidirectional Flyover from Anand Roa Circle and Dr. B.R Ambedkar Road both joins at KR Circle and continue on Nrupathunga road.

13.3 ADVANTAGES AND CONCLUSION.

- Presently traffic along the corridor is heavy as V/C ratio more than 2 and LOS is E to F during the peak hours. Most part of the day, LOS is varying from D to E. With the additional 4 lanes at elevated road and streamline at grade roads to 2 x 7m wide carriage way V/C ratios are brought down at JC Road.
- Through traffic from Minerva junction to Hudson circle is taken on elevated road there by travelling time, which is presently, 20min to 30 min, will come down to 5min to 8min as 8 signals along the corridor is hopped.
- With major part of 2 wheelers, cars and Autos on elevated road, there will be less hindrance to the Public transport vehicles, mainly BMTC, which are plying at grade. Bus Priority lanes can be earmarked at grade along JC Road with which movement of public vehicles including AMBULANCE will be hassle free.
- With the construction of elevated corridor along JC road and Sheshadri Road, through traffic will be unhindered and traveling time will reduce to less than 15 min for traffic from Anand rao circle to RV road, presently which is taking about 30min to 45 min.

- To cater traffic from South to north & east and from North & east to south the elevated road is proposed with Up ramps at Diagonal Road, RV Road, Rajaram Mohan Roy Road, Nrupatunga Road and Down Ramps at RV Road, KG Road and Kasturba Roads and Connecting Loop from Existing BGS flyover to Town Hall flyover.
- With the provision of elevated rotary at Hudson church junction ensuring, weaving lengths for various directional traffic circulation of traffic for various entry and exit ramps are hassle free
- With the elevated rotary at Hudson circle, traffic at grade at Hudson junction, opposite to GBA, which is choking at the peak hours will be relieved to a greater extent.
- Through traffic from Anand Rao Circle to Nrupathunga road will take this facility avoiding 3 major junctions, Palace road and very importantly KR circle, there by reduction of travelling time and waiting time. There will be through access to traffic from Dr. BR Ambedkar Road crossing KR circle. Both traffic can take the proposed elevated corridor from Minerva circle to Hudson circle, there by direct access to southern part of the Bangalore city avoiding 8 signals.

- The proposed alignment is connected to the proposed Tunnel facility by B-Smile which is being proposed from Sarjapura road to Hebbal. Since this corridor is connected to Tunnel at KG Road, this facility will be useful for the traffic going up to Hebbal from south part of Bangalore city.

IN VIEW OF THE ABOVE ADVANTAGES,FROM THE DETAILED STUDY AND DISCUSSIONS, Construction of Elevated Corridors from Minerva Circle to Hudson Circle and loop flyover from existing Bala Gangadhara

Nath Swamiji flyover to Townhall and Elevated Corridors from Sangolli Rayanna circle (Anand Rao Flyover) to Nrupathung road (KR Circle), **VERY ESSENTIAL AND RECOMMENDED.**

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1.0 Introduction

1.1 Project Background

Traffic studies are the initial step of any road project whether it is improvement/upgradation over existing road. This generally considered by way augmentation of existing capacity of road such that, the road would handle the present and future traffic in acceptable level of service. In order to decide upon the type of improvement or upgradation required needs some base line studies related to traffic volume and its composition. These traffic studies are the base for deciding many components such as roadway width, lane width, pavement design etc. All these signify the importance of traffic data. Traffic flow on rural section is different when it is compared with that of an urban road section. In the urban areas, the traffic flow is frequently interrupted with close intersections and continuous ribbon development. When there is a ribbon development is majorly a commercial establishment, this will also affect the through traffic along the corridor due to parking or stopping near commercial establishment. All these conditions warrants for congestion and delay in the traffic flow thereby increase in the travel time leading to unnecessary increase in Vehicle Operation Cost. Presently, the study is under consideration is pertaining to an urban section of an important arterial road in the Bangalore City which has similar type of ground condition and carry maximum volume of passenger vehicles specially Two-Wheelers, Autos and Cars. The road which needs immediate attention is part of Jaya Chamarajendra Road (JC Road) from Minerva Junction to Town Hall Junction and further upto Hudson Circle via Town Hall. It is observed that, there are 5 number of major junctions excluding Minerva Junction and Hudson Circle along the road located at very closely leading to frequent traffic congestion along the JC road.

Therefore, the **Bruhat Bengaluru Mahnagara Palike (BBMP)** has decided to improve the traffic flow along JC road by augmenting the current roadway by adopting Elevated Road from Minerva Junction to Hudson Circle so that the congestion level along JC Road and further up to Hudson Circle may eased to an extent possible.

1.2 Project Description

The project stretch from Minerva Junction to Hudson Circle is about 2.2 Km in length and traverses through following intersections.

(a) **JUNCTION-1:** Minerva Junction (Lalabagh Fort Rpad, RV Road, Sajjan Rao Circle Road, K R Market Road) at Km 0.300

(b) **JUNCTION-2:** JC Road with Armugum Mudaliar Road-Siddaiah Road Junction at Km 0.680

(c) **JUNCTION-3:** JC Road with Shivaji Talkies-Poornima Theatre Junction at Km 1.140

(d) **JUNCTION-4:** Town Hall Junction (JC Road and Nrupathunga Road) at Km 1.440

(e) **JUNCTION-5:** Badami House Junction (JC Road with SP Road and Mission Road) at Km 1.700

(f) **JUNCTION-6:** Halasur Gate Police Station Junction (JC Road with Naganna Road and Raja Ram Mohan Roy Road) at Km 1.80

(g) **JUNCTION-7:** Kempegowda Road (KG Road) Junction (JC Road with Kempegowda Road (KG Road), Nrupathunga Road (NR Road) and Kasturaba Road) at Km 1.92

(h) **JUNCTION-8:** NR Road & RRMR Road Junction (Nrupathunga Road Junction with Rajaram Mohan Roy Road and Devanga Hostel Road Junction) at Hudson Circle

The details of the above junctions have been indicated in location map below.

1.3 Purpose of Traffic Study

Traffic surveys have been carried out on the project corridor in order to identify present and likely future scenarios so as to device suitable remedial measures and to evolve appropriate design method. The primary objectives of these traffic surveys are to determine the characteristics of traffic movement on the project corridor determine the turning movement pattern of traffic at road intersections.

As per the present traffic flow pattern following have been observed;

- The traffic is allowed flow from Minerva Junction to Town Hall in one direction only.

- From Town Hall Junction to Hudson Circle, the traffic is allowed in both direction.
- At all the junctions mentioned above, the traffic flow has been restricted in many directions due high volume of traffic flow. The details of traffic flow are presented in subsequent sections.

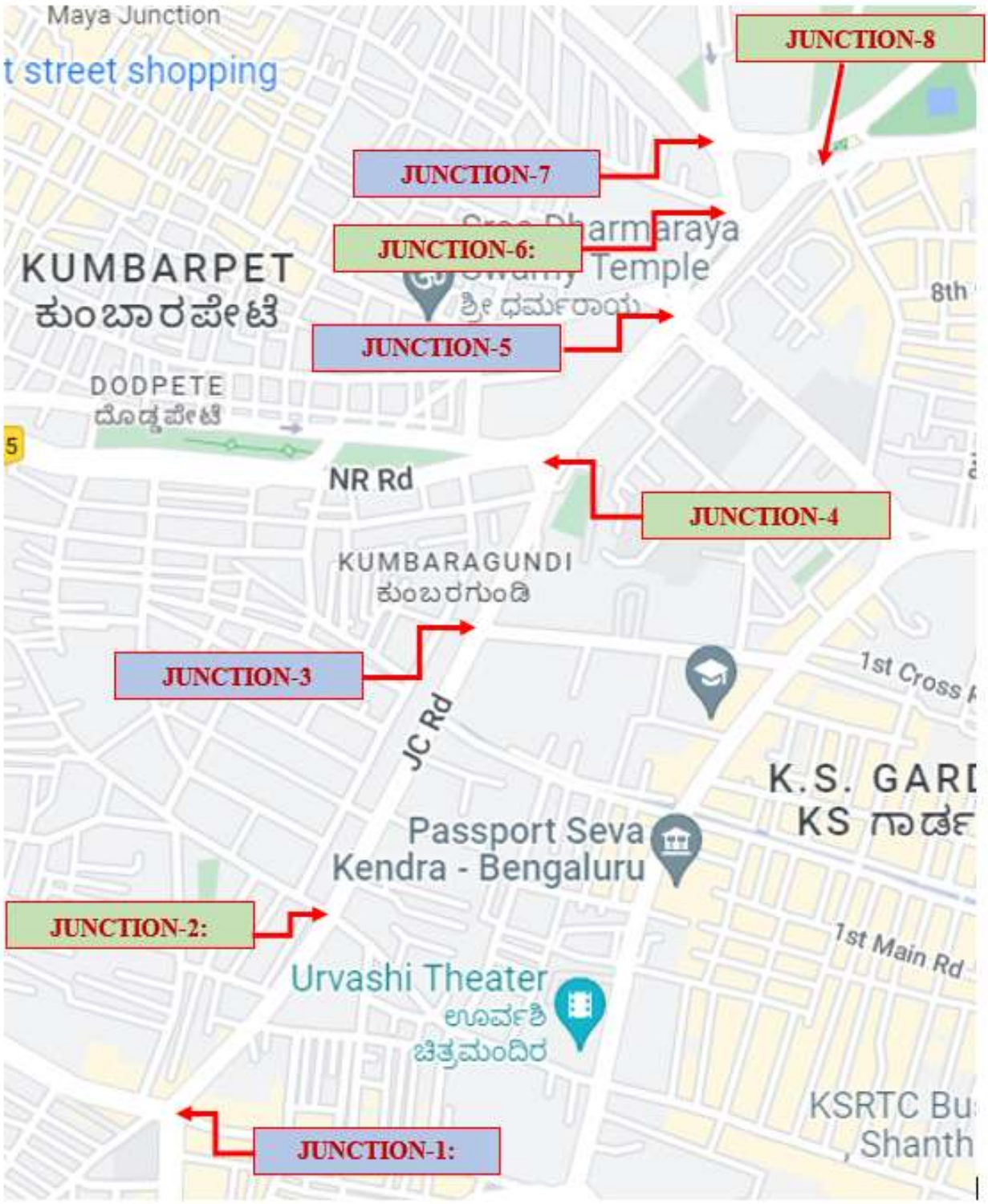


Figure 1-1: Details of Project Stretch

2.0 Traffic Surveys and Analysis

2.1 Traffic Survey

2.1.1 Traffic Survey Locations

The primary surveys were intended to estimate the traffic scenario on the project corridor and to identify necessary requirements to provide an enhanced facility. In order to make a proper assessment of traffic volume, base year traffic and its projection, Consultants, have carried out the necessary traffic surveys and investigations. The base year traffic data is the primary input for determination of future traffic demand. With a view to estimate the base year traffic volume, the Classified Turning Traffic Volume Count (CTTVC) Survey at all the above mentioned junction locations have been conducted. In addition to this, a sample Origin and Destination survey to assess the travel characteristics Minerva Junction and Hudson Circle have been carried out.

The traffic survey locations are selected based on a detailed reconnaissance survey. All the traffic surveys and further analysis is carried out as per the guidelines given in IRC: SP 19-2001, IRC: 108-1996, IRC SP: 41-1994, IRC: 102-1988 and IRC: 09-1972. The traffic volume count survey was conducted during morning peak and evening peak to ascertain the peak hour traffic flow at all these junctions on normal working days from Wednesday to Friday for 3 days.

Table 2-1: Traffic Survey Locations

No	Name of Junctions	Remarks
1	**JUNCTION-1:** Minerva Junction (Lalabagh Fort Rpad, RV Road, Sajjan Rao Circle Road, K R Market Road)	• It is Five Leg Junction. • Presently allowed for 6 major directional traffic flow at junction.
2	**JUNCTION-2:** JC Road with Armugum Mudaliar Road-Siddaiah Road Junction	• It is Four Leg Junction. • Presently allowed for 4 major directional traffic flow at junction.
3	**JUNCTION-3:** JC Road with Shivaji Talkies-Poornima Theatre Junction	• It is Four Leg Junction. • Presently allowed for 6 major directional

No	Name of Junctions	Remarks
		traffic flow at junction.
4	**JUNCTION-4:** Town Hall Junction (JC Road and Nrupathunga Road)	• It is Three Leg Junction. • Presently allowed for 4 major directional traffic flow at junction.
5	**JUNCTION-5:** Badami House Junction (JC Road with SP Road and Mission Road)	• It is Four Leg Junction. • Presently allowed for 4 major directional traffic flow at junction.
6	**JUNCTION-6:** Halasur Gate Police Station Junction (JC Road with Naganna Road and Raja Ram Mohan Roy Road)	• It is Four Leg Junction. • Presently allowed for 4 major directional traffic flow at junction.
7	**JUNCTION-7:** Kempegowda Road (KG Road) Junction (JC Road with Kempegowda Road (KG Road), Nrupathunga Road and Kasturaba Road)	• It is Four Leg Junction. • Presently allowed for 3 major directional traffic flow at junction.
8	**JUNCTION-8:** NR Road & RRMR Road Junction (Nrupathunga Road Junction with Rajaram Mohan Roy Road and Devanga Hostel Road Junction) at Hudson Circle	• It is Four Leg Junction. • Presently allowed for 3 major directional traffic flow at junction.

2.1.2 Passenger Car Units (PCU) For Analysis

All the vehicles need to be converted into common unit. Therefore, as per the guidelines of IRC, the PCU factors as per the recommendations of IRC-106: 1990 were adopted in converting no. of vehicles to PCU since the present stretch of road under study is pertaining to urban area. The PCU values for each type of vehicles are presented in table below.

Table 2-2: PCU Values for Analysis

Vehicles	PCU Values upto 5% Composition	PCU Values above 5% Composition
2 Wheelers	0.5	0.75
Auto Rickshaw	1.2	2
Car/Jeep/Van/Taxi	1.0	1.0
Mini Bus	1.4	2.0
Standard Bus	2.2	3.7
LCV	1.4	2.0
2 Axle Trucks	2.2	3.7
3 Axle Trucks	4.0	5.0
MAVs	4.0	5.0
Tractor With Trailer	4.0	5.0
Tractor Without Trailer	4.0	5.0
Cycle	0.4	0.5
Bullock Cart	1.5	2.0
Horse Drawn Vehicle	1.5	2.0
Hand Drawn Vehicle	2.0	3.0

2.2 Classified Turning Traffic Survey Data Analysis for Junctions

The classified turning traffic volume counts were conducted at eight intersection locations during the peak hours of the normal working days from Wednesday to Friday i.e. from 17/08/2022 to 19/08/2022 to evaluate variation in the peak hour traffic on different days of the week. For the purpose of present study, peak hours have been categorised Morning Peak Hour based on Morning Peak Period from 09.00 am to 12.00 pm and Evening Peak Hour based on Evening Peak Period from 04.00 4m to 07.00 pm.

The detailed analysis of the present traffic data for all the eight junction locations are summarized in terms of Peak hour traffic volume, directional distribution, composition etc.

2.2.1 Minerva Junction

Minerva Junction is a Five leg junction and presently has restricted directional movements at the junction. As per the present traffic flow, following are the directions allowed for traffic movement.

- Lalbagh Fort Road to JC Road
- Lalbagh Fort Road to K R Market.
- RV Road to JC Road
- Sajjan Rao Circle (Diagonal Road) to JC Road
- K R Market to JC Road
- K R Market to R V Road

Based on these traffic flow at the junction, the data collected for the three days has been averaged and summary of the data analysis are presented below for the junction.

Summary of three days Morning Peak Hour and Evening Peak Hours are presented below.

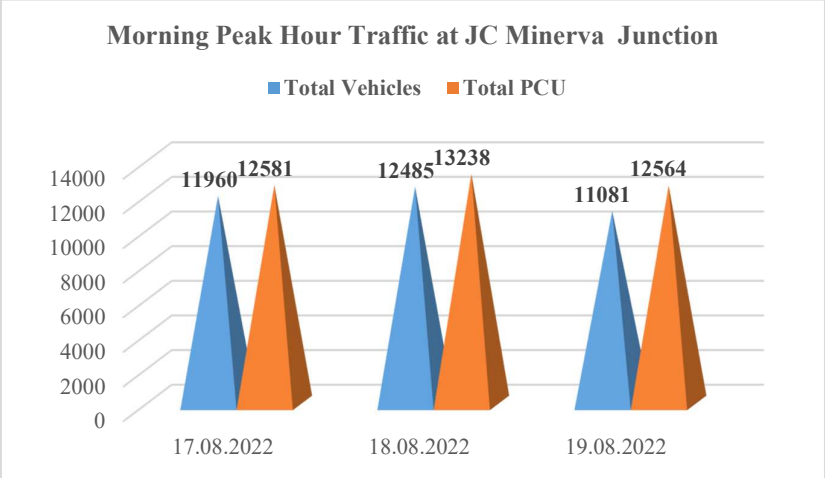
Table 2-3: 3 Days Morning Peak Hour Traffic at Minerva Junction

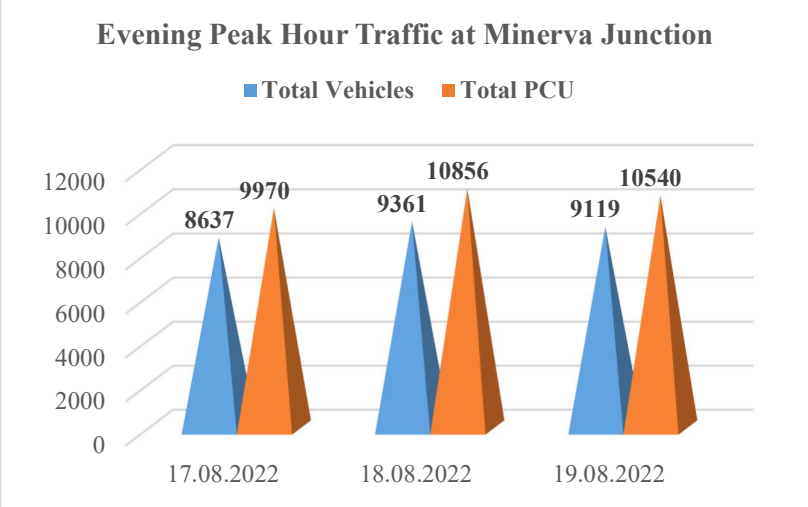
Date	Peak Hour	Total Vehicles	Total PCU
17.08.2022	10.00am to 11.00am	11960	12581
18.08.2022	10.00am to 11.00am	12485	13238
19.08.2022	11.00am to 12.00pm	11081	12564
Average of 17.08.2022 to	**10.00am to 11.00am**	**12094**	**12760**

19.08.2022			

Table 2-4: 3 Days Evening Peak Hour Traffic at Minerva Junction

Date	Peak Hour	Total Vehicles	Total PCU
17.08.2022	04.00pm to 05.00pm	8637	9970
18.08.2022	04.00pm to 05.00pm	9361	10856
19.08.2022	04.00pm to 05.00pm	9119	10540
Average of 17.08.2022 to 19.08.2022	**04.00pm to 05.00pm**	**9039**	**10455**





Detailed Peak hour traffic details including, directional flow, vehicle types, composition, percentage of directional flow are presented in both tables and graphical representation for ready reference below for both morning peak and evening peak hours.

Table 2-5: Summary of Morning Peak Hour Traffic at Minerva Junction

	Vehicles	D-1 to D-4	D-1 to D-5	Total Traffic from D-1	D-2 to D-5	Total Traffic from D-2	D-3 to D-5	Total Traffic from D-3	D-4 to D-2	D-4 to D-5	Total Traffic from D-4	Total from All Directions	Composition of Vehicles
FAST MOVING VEHICLES	2 Wheelers	754	788	**1542**	1738	**1738**	2862	**2862**	200	937	**1137**	**7279**	**60.18%**
	Auto Rickshaw	340	258	**599**	502	**502**	480	**480**	105	394	**499**	**2080**	**17.20%**
	Car/Jeep/Van	264	221	**485**	706	**706**	684	**684**	62	336	**398**	**2273**	**18.79%**
	Min-Bus	11	4	**15**	6	**6**	4	**4**	2	7	**9**	**34**	**0.28%**
	Std. Bus	25	95	**120**	15	**15**	9	**9**	0	93	**93**	**237**	**1.96%**
	LCV	41	28	**69**	18	**18**	24	**24**	5	26	**31**	**142**	**1.17%**
	2 Axle Trucks	17	8	**25**	8	**8**	5	**5**	0	2	**2**	**39**	**0.33%**
	3 Axle Trucks	0	0	**0**	1	**1**	0	**0**	0	1	**1**	**2**	**0.01%**
	MAVs	0	0	**0**	0	**0**	0	**0**	0	0	**0**	**0**	**0.00%**
	Tractor With Trailer	0	0	**0**	0	**0**	1	**1**	0	0	**0**	**1**	**0.01%**
	Tractor Without Trailer	0	0	**0**	0	**0**	0	**0**	0	0	**0**	**0**	**0.00%**
SLOW MOVING VEHICLES	Cycle	2	0	**2**	1	**1**	2	**2**	2	2	**3**	**8**	**0.07%**
	Bullock Cart	0	0	**0**	0	**0**	0	**0**	0	0	**0**	**0**	**0.00%**
	Horse Drawn Vehicle	0	0	**0**	0	**0**	0	**0**	0	0	**0**	**0**	**0.00%**
	Hand Drawn Vehicle	0	0	**0**	0	**0**	0	**0**	0	0	**0**	**0**	**0.00%**

Total Vehicles	**1454**	**1403**	**2857**	**2994**	**2994**	**4070**	**4070**	**375**	**1798**	**2173**	**12094**	**100.00%**
Total PCU	**1675**	**1601**	**3276**	**3100**	**3100**	**3864**	**3864**	**433**	**2087**	**2520**	**12760**	
Directional Distribution	**12.0%**	**11.6%**	**23.6%**	**24.8%**	**24.8%**	**33.7%**	**33.7%**	**3.1%**	**14.9%**	**18.0%**	**100.0%**	

Table 2-6: Summary of Evening Peak Hour Traffic at Minerva Junction

	Vehicles	D-1 to D-4	D-1 to D-5	Total Traffic from D-1	D-2 to D-5	Total Traffic from D-2	D-3 to D-5	Total Traffic from D-3	D-4 to D-2	D-4 to D-5	Total Traffic from D-4	Total from All Directions	Composition of Vehicles
FAST MOVING VEHICLES	**2 Wheelers**	523	644	**1167**	1100	**1100**	988	**988**	163	745	**908**	**4163**	46.06%
	Auto Rickshaw	243	348	**591**	600	**600**	326	**326**	98	413	**511**	**2028**	22.44%
	Car/Jeep/Van	389	270	**659**	570	**570**	492	**492**	110	470	**580**	**2302**	25.46%
	Min-Bus	11	5	**16**	8	**8**	5	**5**	0	12	**12**	**41**	0.45%
	Std. Bus	20	111	**131**	17	**17**	10	**10**	0	85	**85**	**242**	2.68%
	LCV	43	46	**89**	28	**28**	18	**18**	7	71	**78**	**213**	2.36%
	2 Axle Trucks	17	8	**25**	6	**6**	3	**3**	0	1	**1**	**35**	0.39%
	3 Axle Trucks	0	0	**0**	0	**0**	0	**0**	0	0	**0**	**0**	0.00%
	MAVs	0	0	**0**	0	**0**	0	**0**	0	0	**0**	**0**	0.00%
	Tractor With Trailer	0	0	**0**	0	**0**	0	**0**	0	1	**1**	**1**	0.01%
	Tractor Without Trailer	0	0	**0**	0	**0**	0	**0**	0	0	**0**	**0**	0.00%

SLOW MOVING VEHICLES	Cycle	1	0	**1**	2	**2**	2	**2**	5	4	**9**	**14**	0.15%
	Bullock Cart	0	0	**0**	0	**0**	0	**0**	0	0	**0**	**0**	0.00%
	Horse Drawn Vehicle	0	0	**0**	0	**0**	0	**0**	0	0	**0**	**0**	0.00%
	Hand Drawn Vehicle	0	0	**0**	0	**0**	0	**0**	0	0	**0**	**0**	0.00%
Total Vehicles		**1247**	**1431**	**2679**	**2332**	**2332**	**1844**	**1844**	**383**	**1802**	**2185**	**9039**	**100.00%**
Total PCU		**1425**	**1781**	**3206**	**2697**	**2697**	**1946**	**1946**	**440**	**2166**	**2606**	**10455**	
Directional Distribution		**13.8%**	**15.8%**	**29.6%**	**25.8%**	**25.8%**	**20.4%**	**20.4%**	**4.2%**	**19.9%**	**24.2%**	**100.0%**	

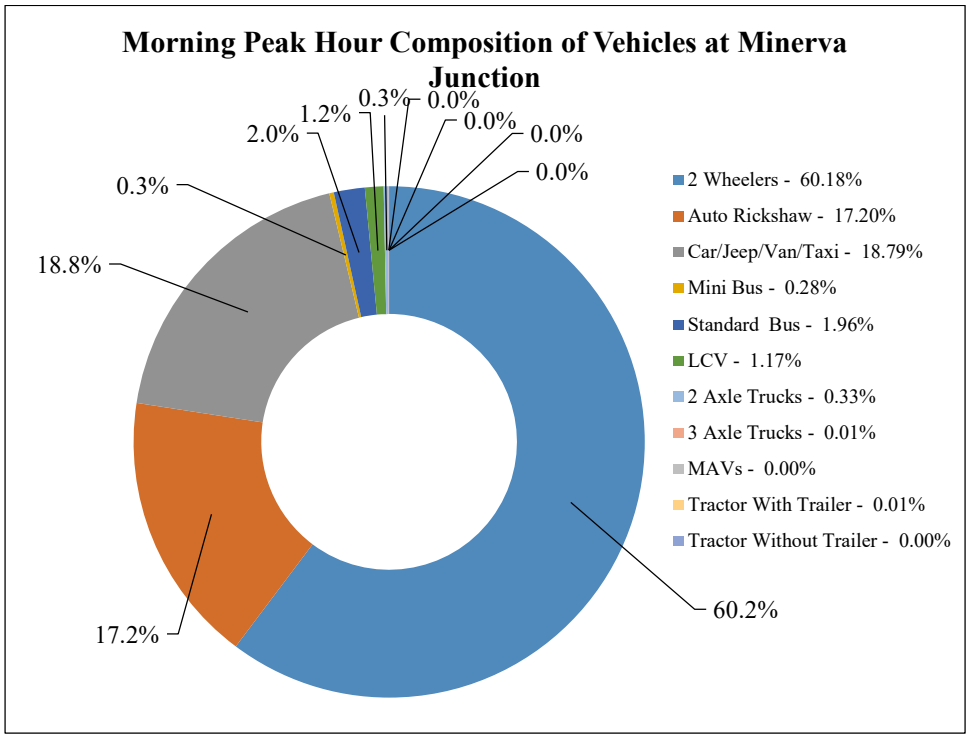


Figure 2-1: Morning Peak Hour Composition at Minerva Junction

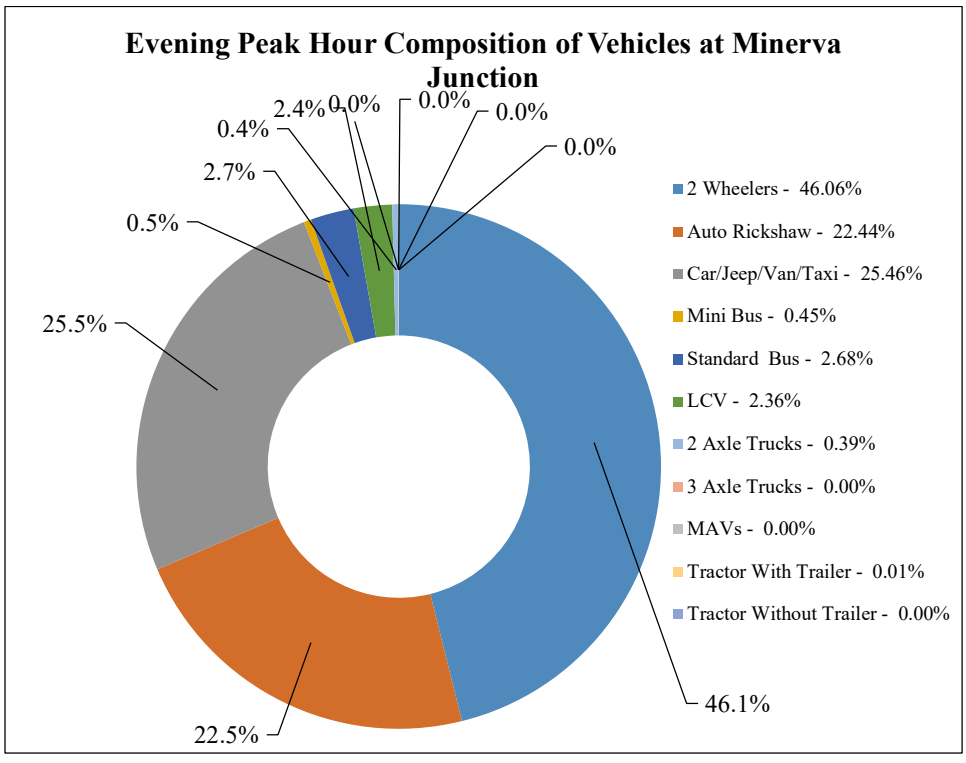


Figure 2-2: Evening Peak Hour Composition at Minerva Junction

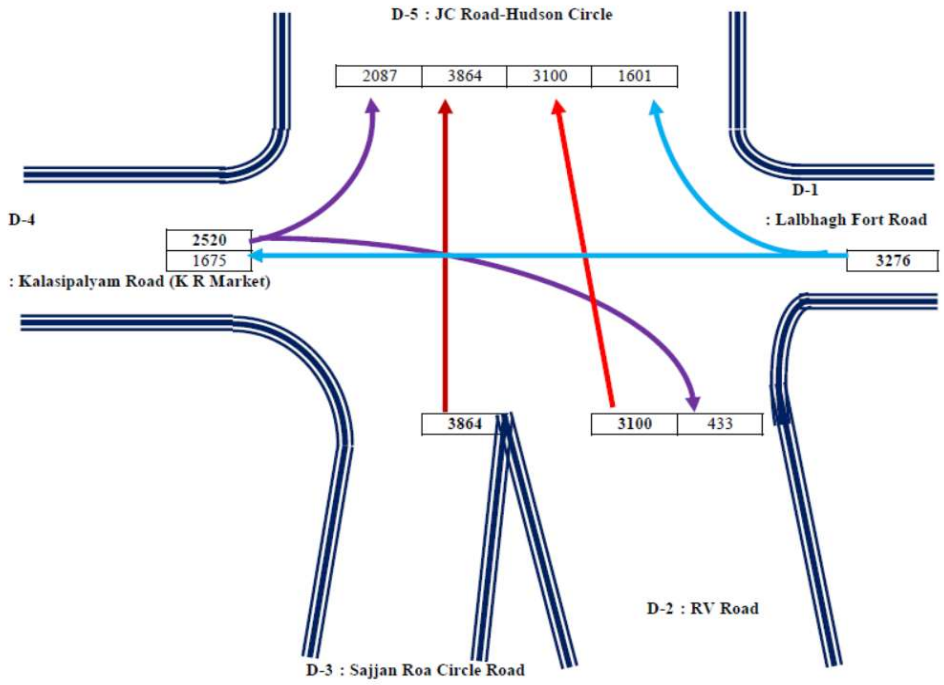


Figure 2-3: Morning Peak Hour Traffic Flow at Minerva Junction

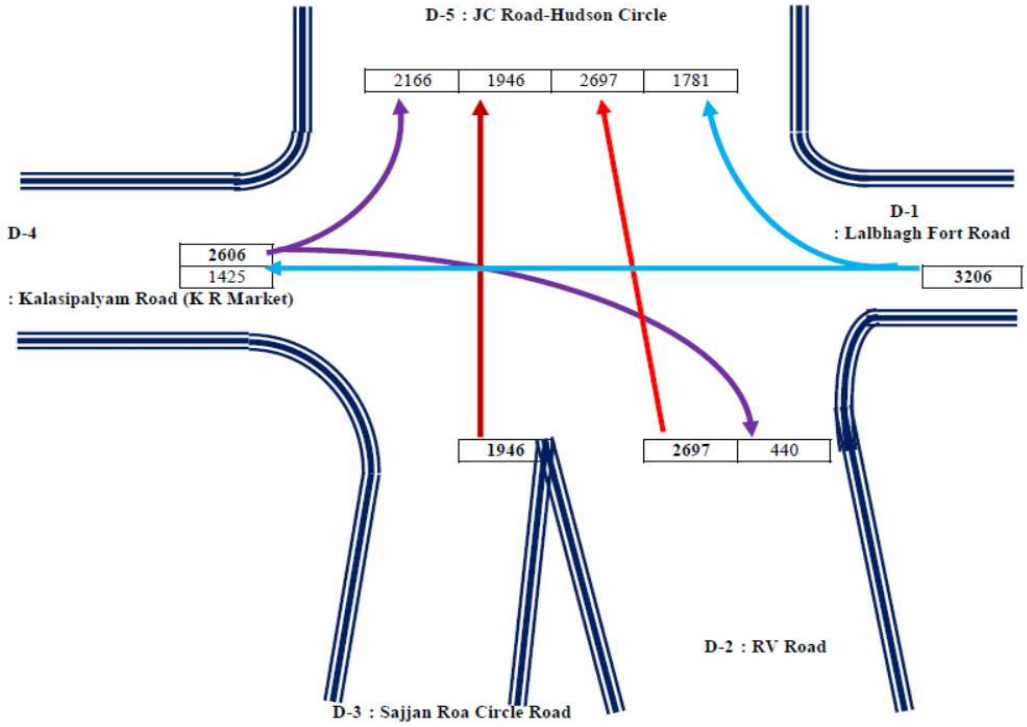


Figure 2-4: Evening Peak Hour Traffic Flow at Minerva Junction

2.2.2 JC Road with Armugum Mudaliar Road-Siddaiah Road Junction

JC Road with Armugum Mudaliar Road-Siddaiah Road Junction is a Four leg junction and presently has restricted directional movements at the junction. As per the present traffic flow, following are the directions allowed for traffic movement.

- Minerva Junction to Hudson Circle (JC Road)
- Minerva Junction to Siddaiah Road (Urvashi Theatre)
- Armugam Mudaliar Road to Hudson Circle (JC Road)
- Armugam Mudaliar Road to Siddaiah Road (Urvashi Theatre)

Based on these traffic flow at the junction, the data collected for the three days has been averaged and summary of the data analysis are presented below for the junction.

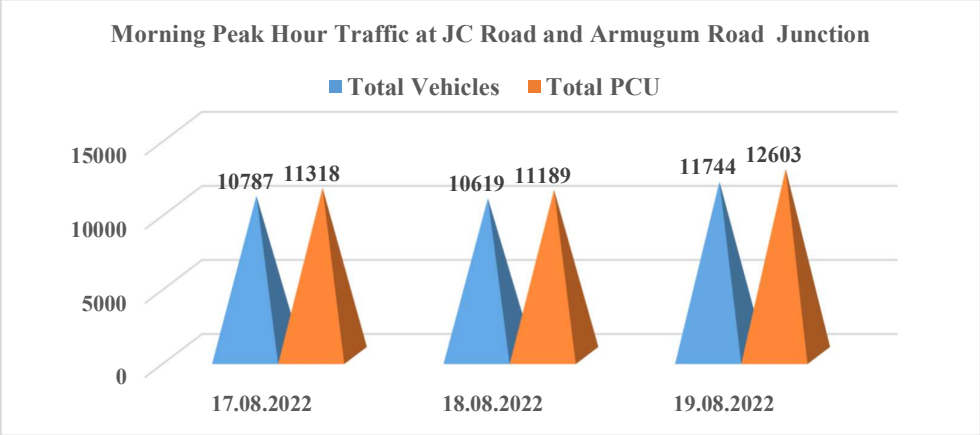
Summary of three days Morning Peak Hour and Evening Peak Hours are presented below.

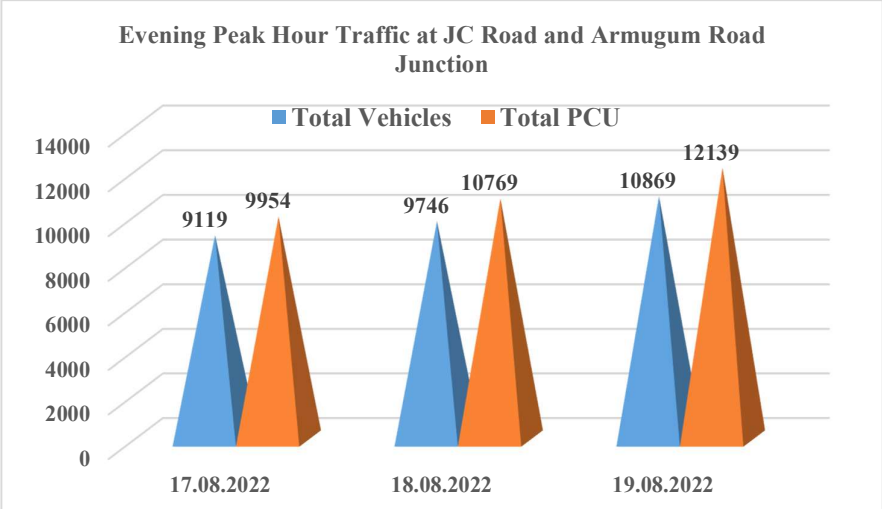
Table 2-7: 3 Days Morning Peak Hour Traffic at JC Road with Armugum Mudaliar Road-Siddaiah Road Junction

Date	Peak Hour	Total Vehicles	Total PCU
17.08.2022	11.00am to 12.00pm	10787	11318
18.08.2022	11.00am to 12.00pm	10619	11189
19.08.2022	11.00am to 12.00pm	11744	12603
Average of 17.08.2022 to 19.08.2022	**11.00am to 12.00pm**	**11050**	**11704**

Table 2-8: 3 Days Evening Peak Hour Traffic at JC Road with Armugum Mudaliar Road-Siddaiah Road Junction

Date	Peak Hour	Total Vehicles	Total PCU
17.08.2022	04.00pm to 05.00pm	9119	9954
18.08.2022	04.00pm to 05.00pm	9746	10769
19.08.2022	04.00pm to 05.00pm	10869	12139
Average of 17.08.2022 to 19.08.2022	**04.00pm to 05.00pm**	**9911**	**10954**





Detailed Peak hour traffic details including, directional flow, vehicle types, composition, percentage of directional flow are presented in both tables and graphical representation for ready reference below for both morning peak and evening peak hours.

Table 2-9: Summary of Morning Peak Hour Traffic at JC Road with Armugum Mudaliar Road-Siddaiah Road Junction

Vehicles		D-1 to D-3	D-1 to D-4	Total Traffic from D-1	D-2 to D-3	D-2 to D-4	Total Traffic from D-2	Total from All Directions	Composition of Vehicles
FAST MOVING VEHICLES	2 Wheelers	4607	1065	**5672**	213	619	**832**	**6504**	**58.86%**
	Auto Rickshaw	1102	386	**1488**	94	265	**359**	**1847**	**16.71%**
	Car/Jeep/Van	1362	569	**1930**	42	207	**249**	**2179**	**19.72%**
	Min-Bus	11	17	**27**	0	3	**3**	**30**	**0.27%**
	Std. Bus	96	111	**207**	0	0	**0**	**207**	**1.87%**
	LCV	62	69	**131**	30	67	**97**	**227**	**2.06%**
	2 Axle Trucks	18	7	**25**	4	9	**13**	**38**	**0.34%**
	3 Axle Trucks	11	0	**11**	0	0	**0**	**11**	**0.10%**
	MAVs	0	1	**1**	0	0	**0**	**1**	**0.01%**
	Tractor With Trailer	1	0	**1**	0	0	**0**	**1**	**0.01%**
	Tractor Without Trailer	0	0	**0**	0	0	**0**	**0**	**0.00%**
SLOW MOVING VEHICLES	Cycle	1	0	**1**	1	2	**3**	**4**	**0.04%**
	Bullock Cart	0	0	**0**	0	0	**0**	**0**	**0.00%**
	Horse Drawn Vehicle	0	0	**0**	0	0	**0**	**0**	**0.00%**
	Hand Drawn Vehicle	0	0	**0**	0	0	**0**	**0**	**0.00%**
Total Vehicles		**7271**	**2224**	**9494**	**384**	**1172**	**1556**	**11050**	**100.00%**

Total PCU	**7422**	**2522**	**9944**	**440**	**1320**	**1760**	**11704**	**0**
Directional Distribution	**65.8%**	**20.1%**	**85.9%**	**3.5%**	**10.6%**	**14.1%**	**100.0%**	**0.0%**

Table 2-10: Summary of Evening Peak Hour Traffic at JC Road with Armugum Mudaliar Road-Siddaiah Road Junction

Vehicles		D-1 to D-3	D-1 to D-4	Total Traffic from D-1	D-2 to D-3	D-2 to D-4	Total Traffic from D-2	Total from All Directions	Composition of Vehicles
FAST MOVING VEHICLES	**2 Wheelers**	3288	1134	**4422**	266	536	**802**	**5224**	52.71%
	Auto Rickshaw	938	621	**1560**	118	247	**365**	**1925**	19.42%
	Car/Jeep/Van	1380	582	**1962**	74	180	**254**	**2216**	22.36%
	Min-Bus	8	10	**18**	0	2	**2**	**20**	0.20%
	Std. Bus	125	102	**227**	0	0	**0**	**227**	2.29%
	LCV	107	62	**169**	33	67	**100**	**269**	2.72%
	2 Axle Trucks	7	9	**16**	3	3	**6**	**22**	0.22%
	3 Axle Trucks	3	0	**3**	0	0	**0**	**3**	0.03%
	MAVs	0	0	**0**	0	0	**0**	**0**	0.00%
	Tractor With Trailer	0	1	**1**	0	0	**0**	**1**	0.01%
	Tractor Without Trailer	0	0	**0**	0	0	**0**	**0**	0.00%
NON MOVING VEHICLES	**Cycle**	1	0	**1**	2	1	**3**	**4**	0.04%

	Bullock Cart	0	0	**0**	0	0	**0**	**0**	0.00%
	Horse Drawn Vehicle	0	0	**0**	0	0	**0**	**0**	0.00%
	Hand Drawn Vehicle	0	0	**0**	0	0	**0**	**0**	0.00%
Total Vehicles		**5857**	**2522**	**8379**	**496**	**1037**	**1533**	**9911**	**100.00%**
Total PCU		**6186**	**3024**	**9210**	**564**	**1180**	**1744**	**10954**	**0**
Directional Distribution		**59.1%**	**25.4%**	**84.5%**	**5.0%**	**10.5%**	**15.5%**	**100.0%**	**0.0%**

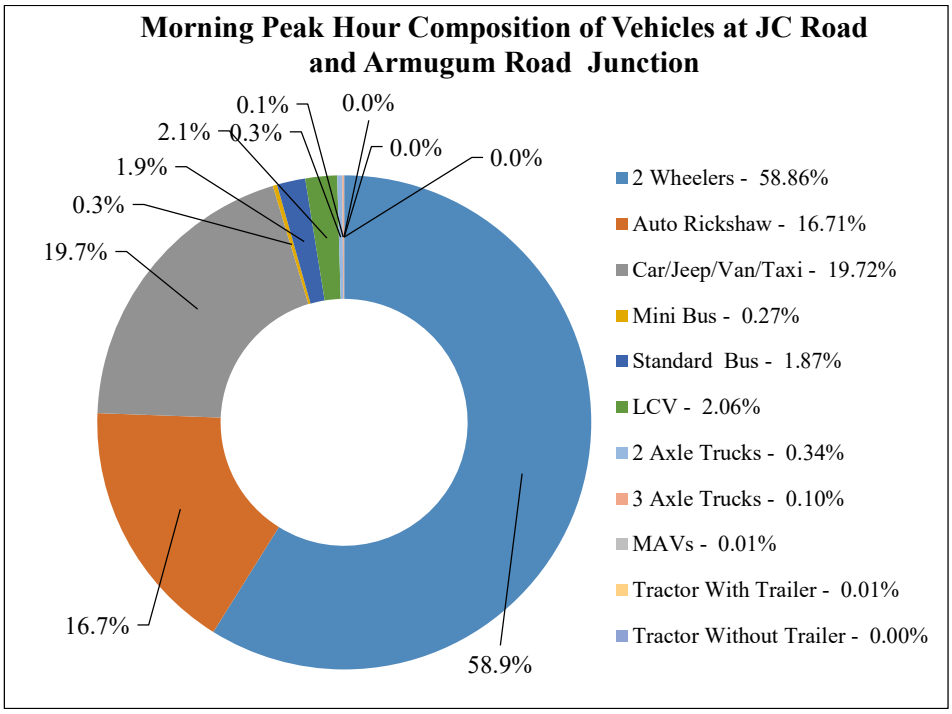


Figure 2-5: Morning Peak Hour Composition at JC Road with Armugum Mudaliar Road-Siddaiah Road Junction

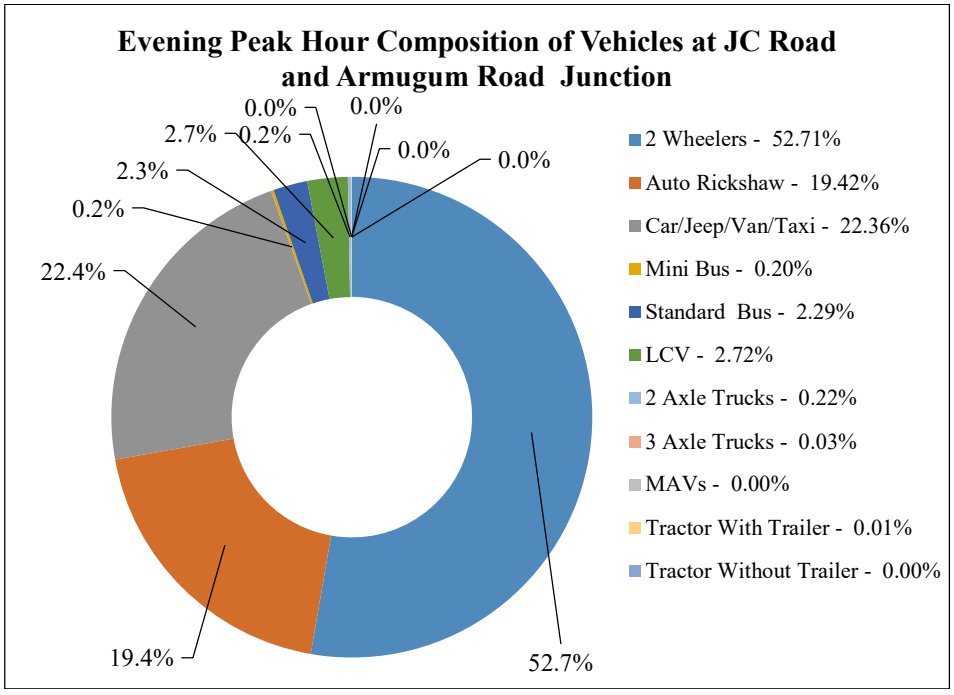


Figure 2-6: Evening Peak Hour Composition at JC Road with Armugum Mudaliar Road-Siddaiah Road Junction

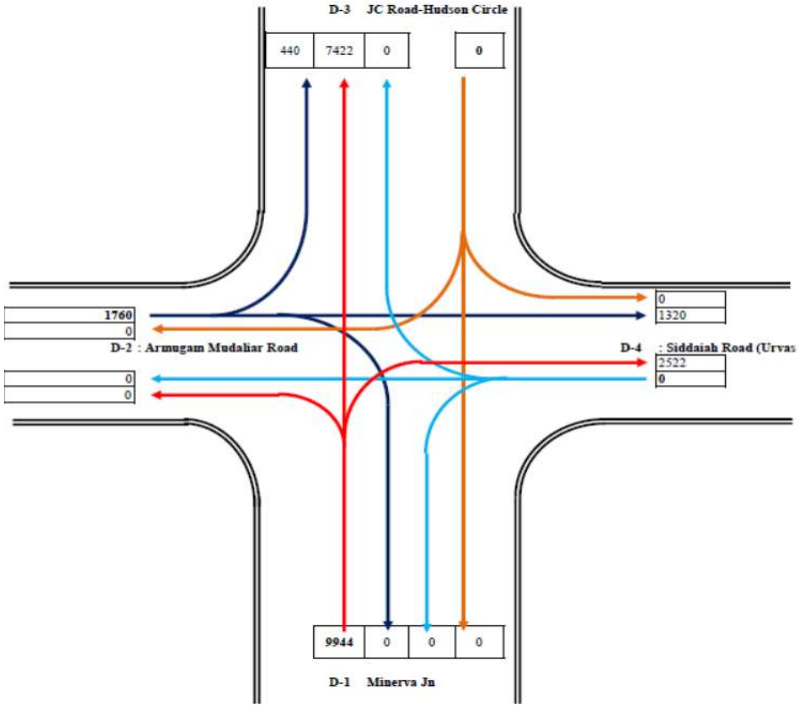


Figure 2-7: Morning Peak Hour Traffic Flow at JC Road with Armugum Mudaliar Road-Siddaiah Road Junction

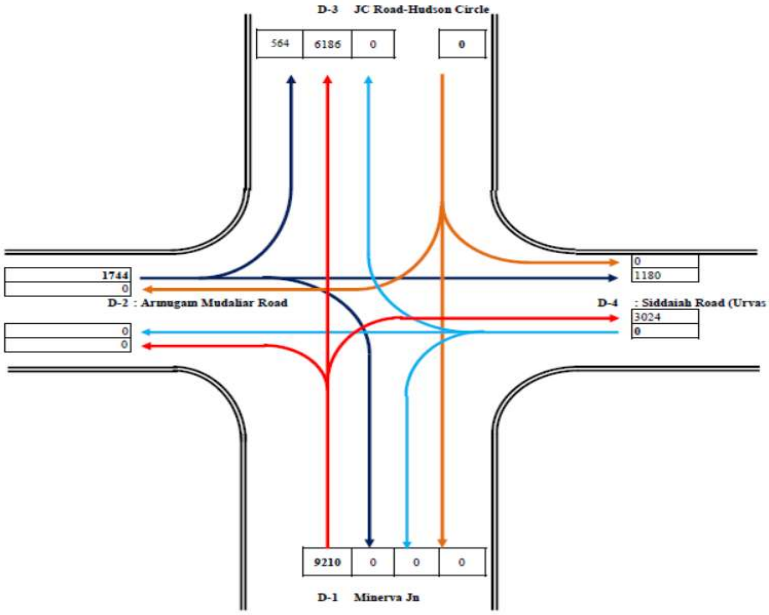


Figure 2-8: Evening Peak Hour Traffic Flow at JC Road with Armugum Mudaliar Road-Siddaiah Road Junction

2.2.3 JC Road with Shivaji Talkies-Poornima Theatre Junction

JC Road with Shivaji Talkies-Poornima Theatre Junction is a Four leg junction and presently has restricted directional movements at the junction. As per the present traffic flow, following are the directions allowed for traffic movement.

- Minerva Junction to Hudson Circle (JC Road)
- Minerva Junction to Poornima Theatre Road
- K R Market (1st Cross Road) to Hudson Circle (JC Road)
- K R Market (1st Cross Road) to Poornima Theatre Road
- Poornima Theatre Road to Hudson Circle (JC Road)
- Poornima Theatre Road to K R Market (1st Cross Road)

Based on these traffic flow at the junction, the data collected for the three days has been averaged and summary of the data analysis are presented below for the junction.

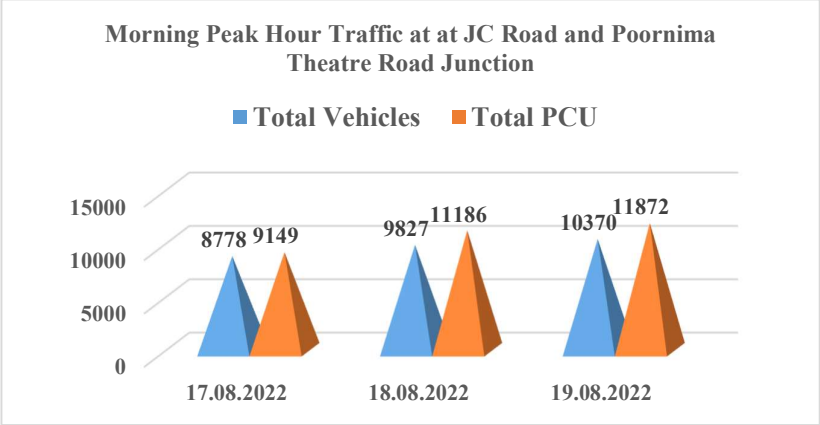
Summary of three days Morning Peak Hour and Evening Peak Hours are presented below.

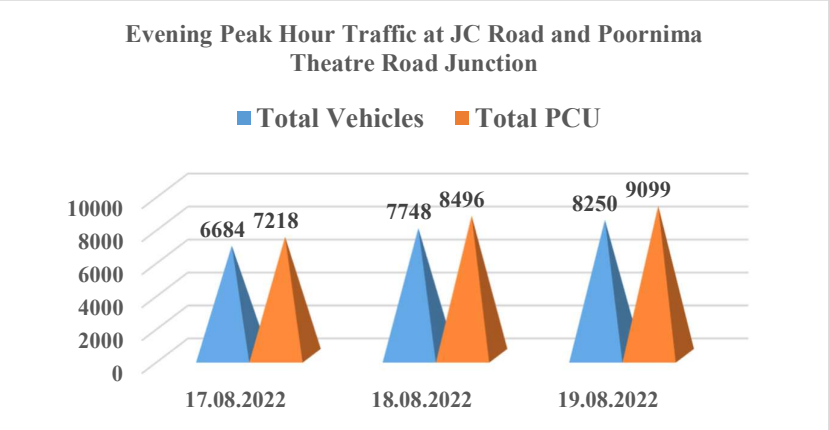
Table 2-11: 3 Days Morning Peak Hour Traffic at JC Road with Shivaji Talkies-Poornima Theatre Junction

Date	Peak Hour	Total Vehicles	Total PCU
17.08.2022	10.00am to 11.00am	8778	9149
18.08.2022	09.00am to 10.00am	9827	11186
19.08.2022	09.00am to 10.00am	10370	11872
Average of 17.08.2022 to 19.08.2022	**09.00am to 10.00am**	**9608**	**10700**

Table 2-12: 3 Days Evening Peak Hour Traffic at JC Road with Shivaji Talkies-Poornima Theatre Junction

Date	Peak Hour	Total Vehicles	Total PCU
17.08.2022	04.00pm to 05.00pm	6684	7218
18.08.2022	04.00pm to 05.00pm	7748	8496
19.08.2022	04.00pm to 05.00pm	8250	9099
Average of 17.08.2022 to 19.08.2022	**04.00pm to 05.00pm**	**7561**	**8271**





Detailed Peak hour traffic details including, directional flow, vehicle types, composition, percentage of directional flow are presented in both tables and graphical representation for ready reference below for both morning peak and evening peak hours.

Table 2-13: Summary of Morning Peak Hour Traffic at JC Road with Shivaji Talkies-Poornima Theatre Junction

Vehicles		D-1 to D-3	D-1 to D-4	Total Traffic from D-1	D-2 to D-3	D-2 to D-4	Total Traffic from D-2	D-4 to D-2	D-4 to D-3	Total Traffic from D-4	Total from All Directions	Composition of Vehicles
FAST MOVING VEHICLES	2 Wheelers	2935	1599	**4534**	125	175	**300**	162	371	**533**	**5367**	**55.86%**
	Auto Rickshaw	648	909	**1557**	8	72	**80**	138	270	**408**	**2045**	**21.28%**
	Car/Jeep/Van	1230	238	**1468**	5	18	**23**	70	161	**231**	**1722**	**17.92%**
	Min-Bus	18	5	**23**	0	0	**0**	0	6	**6**	**29**	**0.31%**
	Std. Bus	184	0	**184**	0	0	**0**	0	13	**13**	**197**	**2.05%**
	LCV	93	16	**109**	6	7	**14**	19	36	**55**	**177**	**1.84%**
	2 Axle Trucks	18	2	**20**	0	0	**0**	14	15	**29**	**49**	**0.51%**
	3 Axle Trucks	3	0	**3**	1	0	**1**	0	0	**0**	**4**	**0.04%**
	MAVs	2	0	**2**	0	0	**0**	0	0	**0**	**2**	**0.02%**
	Tractor With Trailer	0	0	**0**	0	0	**0**	0	1	**1**	**1**	**0.01%**
	Tractor Without Trailer	0	0	**0**	0	0	**0**	0	0	**0**	**0**	**0.00%**
SLOW MOVING VEHICLES	Cycle	7	4	**11**	0	0	**0**	0	5	**5**	**16**	**0.16%**
	Bullock Cart	0	0	**0**	0	0	**0**	0	0	**0**	**0**	**0.00%**
	Horse Drawn Vehicle	0	0	**0**	0	0	**0**	0	0	**0**	**0**	**0.00%**
	Hand Drawn Vehicle	0	0	**0**	0	0	**0**	0	0	**0**	**0**	**0.00%**

Total Vehicles	**5138**	**2773**	**7910**	**145**	**273**	**418**	**402**	**878**	**1280**	**9608**	**100.00%**
Total PCU	**5349**	**3291**	**8640**	**127**	**304**	**431**	**524**	**1104**	**1629**	**10700**	
Directional Distribution	**53.5%**	**28.9%**	**82.3%**	**1.5%**	**2.8%**	**4.3%**	**4.2%**	**9.1%**	**13.3%**	**100.0%**	

Table 2-14: Summary of Evening Peak Hour Traffic at JC Road with Shivaji Talkies-Poornima Theatre Junction

Vehicles		D-1 to D-3	D-1 to D-4	Total Traffic from D-1	D-2 to D-3	D-2 to D-4	Total Traffic from D-2	D-4 to D-2	D-4 to D-3	Total Traffic from D-4	Total from All Directions	Composition of Vehicles
FAST MOVING VEHICLES	**2 Wheelers**	2082	765	**2847**	87	147	**234**	262	558	**820**	**3901**	51.59%
	Auto Rickshaw	597	327	**924**	27	100	**127**	65	276	**342**	**1392**	18.42%
	Car/Jeep/Van	1158	253	**1411**	5	7	**12**	130	310	**441**	**1863**	24.65%
	Min-Bus	28	5	**33**	0	0	**0**	0	4	**4**	**38**	0.50%
	Std. Bus	135	0	**135**	0	0	**0**	0	10	**10**	**145**	1.92%
	LCV	46	58	**104**	11	7	**18**	31	33	**64**	**185**	2.45%
	2 Axle Trucks	6	0	**6**	0	0	**0**	12	3	**14**	**21**	0.27%
	3 Axle Trucks	3	0	**3**	0	0	**0**	0	0	**0**	**3**	0.04%
	MAVs	0	0	**0**	0	0	**0**	0	0	**0**	**0**	0.00%
	Tractor With Trailer	0	0	**0**	0	0	**0**	0	1	**1**	**1**	0.01%
	Tractor Without	0	0	**0**	0	0	**0**	0	0	**0**	**0**	0.00%

	Trailer											
SLOW MOVING VEHICLES	**Cycle**	4	5	**9**	2	0	**2**	0	0	**0**	**11**	0.15%
	Bullock Cart	0	0	**0**	0	0	**0**	0	0	**0**	**0**	0.00%
	Horse Drawn Vehicle	0	0	**0**	0	0	**0**	0	0	**0**	**0**	0.00%
	Hand Drawn Vehicle	0	0	**0**	0	0	**0**	0	0	**0**	**0**	0.00%
Total Vehicles		**4060**	**1412**	**5472**	**132**	**261**	**393**	**501**	**1195**	**1696**	**7561**	**100.00%**
Total PCU		**4344**	**1570**	**5913**	**140**	**327**	**467**	**527**	**1364**	**1891**	**8271**	
Directional Distribution		**53.7%**	**18.7%**	**72.4%**	**1.7%**	**3.4%**	**5.2%**	**6.6%**	**15.8%**	**22.4%**	**100.0%**	

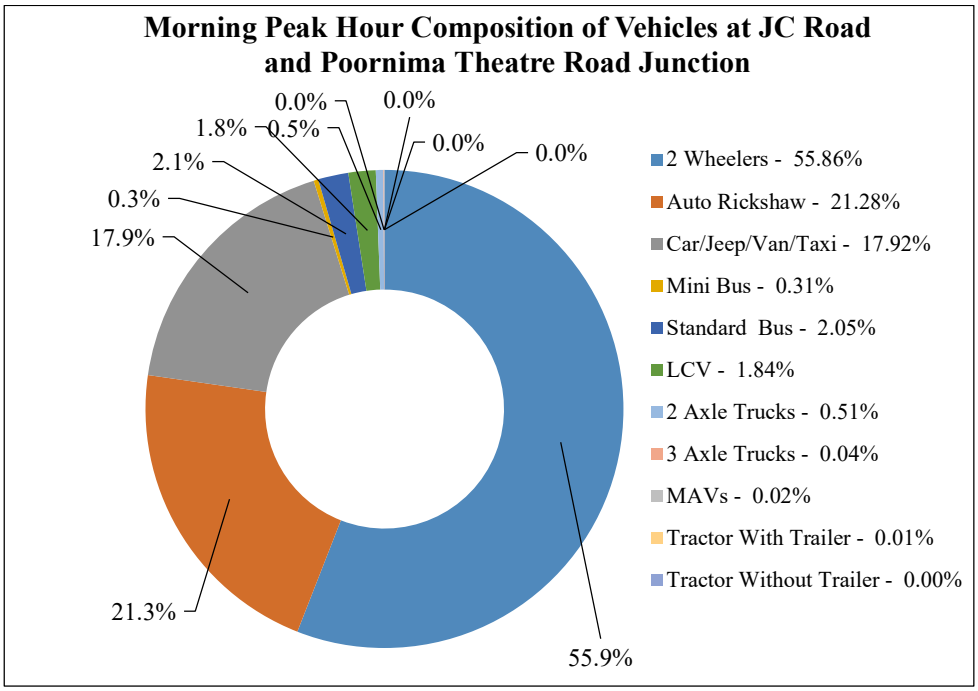


Figure 2-9: Morning Peak Hour Composition at JC Road with Shivaji Talkies-Poornima Theatre Junction

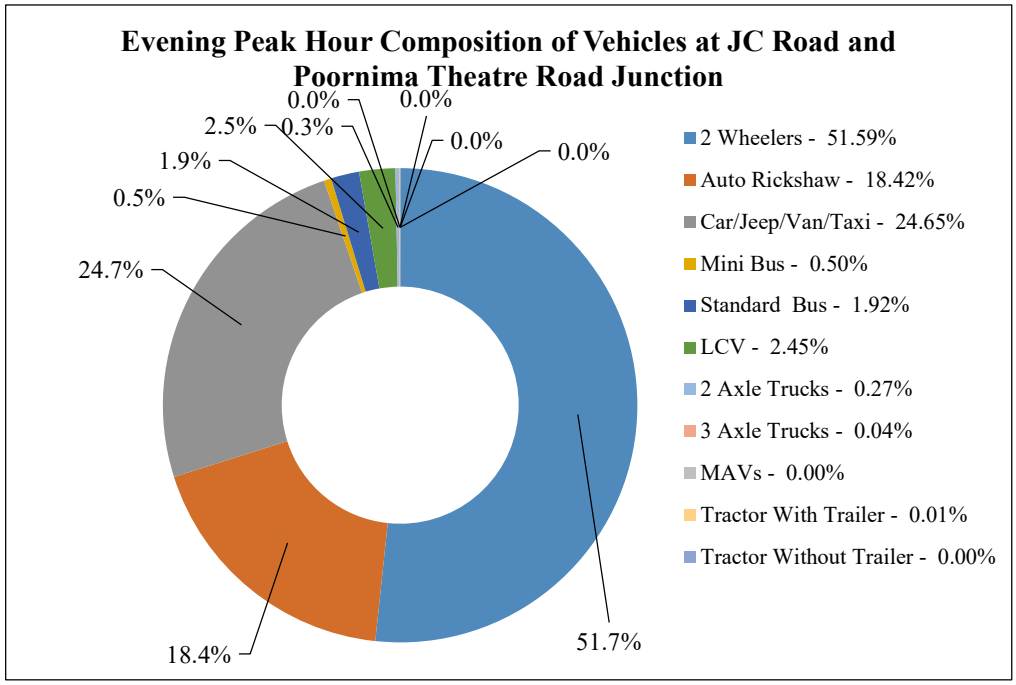


Figure 2-10: Evening Peak Hour Composition at JC Road with Shivaji Talkies-Poornima Theatre Junction

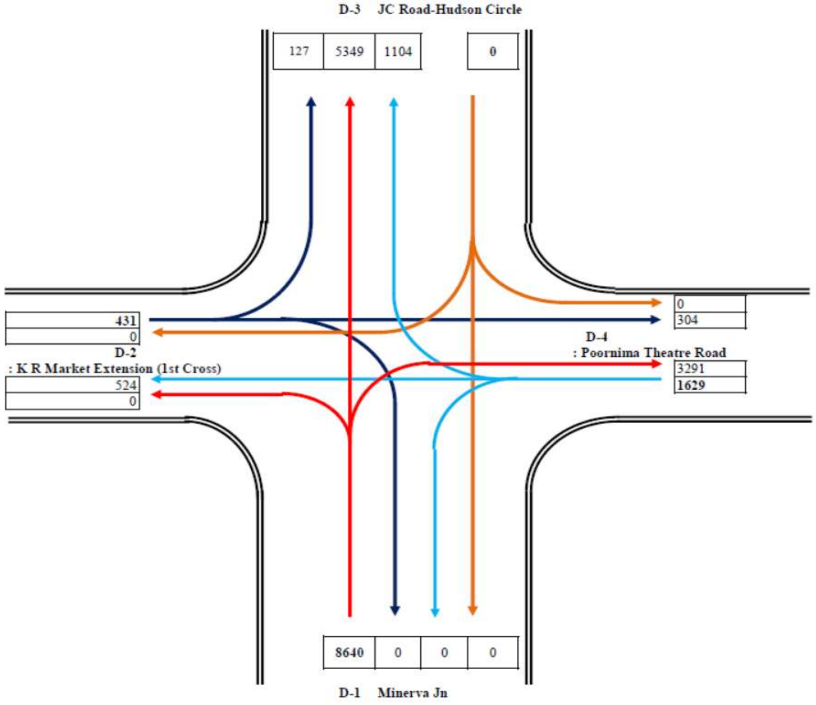


Figure 2-11: Morning Peak Hour Traffic Flow at JC Road with Shivaji Talkies-Poornima Theatre Junction

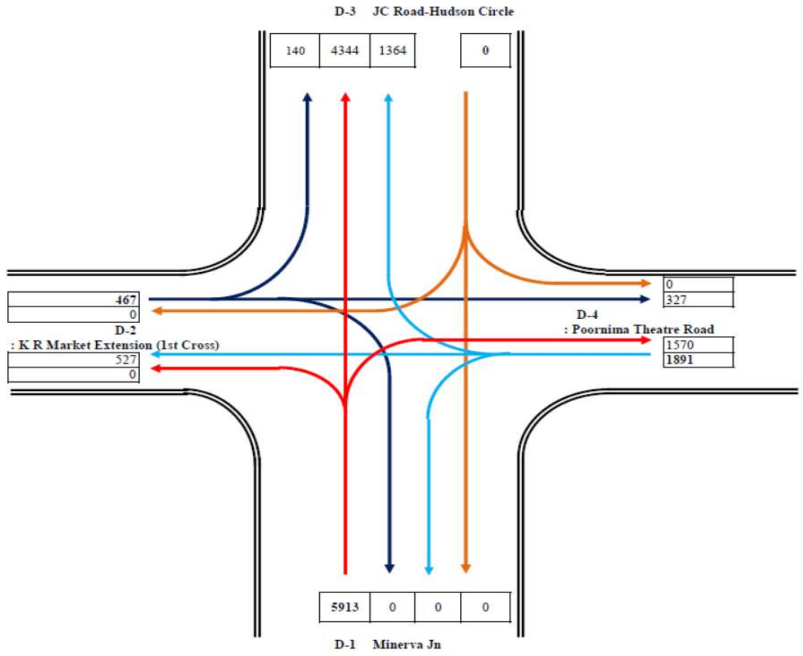


Figure 2-12: Evening Peak Hour Traffic Flow at JC Road with Shivaji Talkies-Poornima Theatre Junction

2.2.4 Town Hall Junction

Town Hall Junction is a three-leg junction and presently has restricted directional movements at the junction. As per the present traffic flow, following are the directions allowed for traffic movement.

- Minerva Junction to Hudson Circle (JC Road)
- Minerva Junction to Nrupathunga Road (K R Market)
- Nrupathunga Road (K R Market) to Hudson Circle (JC Road)
- Hudson Circle to Nrupathunga Road (K R Market)

Based on these traffic flow at the junction, the data collected for the three days has been averaged and summary of the data analysis are presented below for the junction.

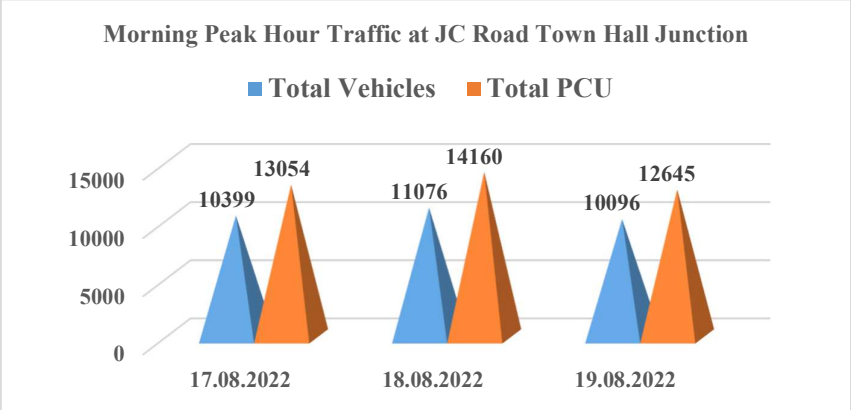
Summary of three days Morning Peak Hour and Evening Peak Hours are presented below.

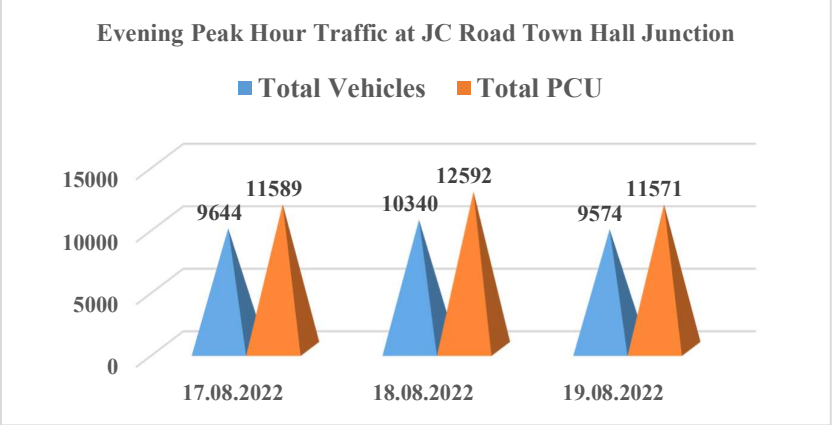
Table 2-15: 3 Days Morning Peak Hour Traffic at Town Hall Junction

Date	Peak Hour	Total Vehicles	Total PCU
17.08.2022	11.00am to 12.00pm	10399	13054
18.08.2022	11.00am to 12.00pm	11076	14160
19.08.2022	11.00am to 12.00pm	10096	12645
Average of 17.08.2022 to 19.08.2022	**11.00am to 12.00pm**	**10524**	**13286**

Table 2-16: 3 Days Evening Peak Hour Traffic at Town Hall Junction

Date	Peak Hour	Total Vehicles	Total PCU
17.08.2022	05.00pm to 06.00pm	9644	11589
18.08.2022	05.00pm to 06.00pm	10340	12592
19.08.2022	06.00pm to 07.00pm	9574	11571
Average of 17.08.2022 to 19.08.2022	**05.00pm to 06.00pm**	**9758**	**11800**





Detailed Peak hour traffic details including, directional flow, vehicle types, composition, percentage of directional flow are presented in both tables and graphical representation for ready reference below for both morning peak and evening peak hours.

Table 2-17: Summary of Morning Peak Hour Traffic at Town Hall Junction

Vehicles		D-1 to D-2	D-1 to D-3	Total Traffic from D-1	D-2 to D-3	Total Traffic from D-2	D-3 to D-2	Total Traffic from D-3	Total from All Directions	Composition of Vehicles
FAST MOVING VEHICLES	2 Wheelers	874	1263	**2138**	993	**993**	1787	**1787**	**4917**	**46.73%**
	Auto Rickshaw	410	387	**797**	459	**459**	708	**708**	**1964**	**18.66%**
	Car/Jeep/Van	469	815	**1284**	534	**534**	788	**788**	**2606**	**24.76%**
	Min-Bus	15	15	**30**	59	**59**	25	**25**	**114**	**1.09%**
	Std. Bus	211	113	**324**	196	**196**	150	**150**	**671**	**6.37%**
	LCV	65	16	**81**	33	**33**	53	**53**	**167**	**1.58%**
	2 Axle Trucks	16	13	**29**	32	**32**	23	**23**	**84**	**0.80%**
	3 Axle Trucks	1	0	**1**	0	**0**	0	**0**	**1**	**0.01%**
	MAVs	0	0	**0**	0	**0**	0	**0**	**0**	**0.00%**
	Tractor With Trailer	0	0	**0**	0	**0**	0	**0**	**0**	**0.00%**
	Tractor Without Trailer	0	0	**0**	0	**0**	0	**0**	**0**	**0.00%**
SLOW MOVING VEHICLES	Cycle	0	0	**0**	0	**0**	0	**0**	**0**	**0.00%**
	Bullock Cart	0	0	**0**	0	**0**	0	**0**	**0**	**0.00%**
	Horse Drawn Vehicle	0	0	**0**	0	**0**	0	**0**	**0**	**0.00%**
	Hand Drawn Vehicle	0	0	**0**	0	**0**	0	**0**	**0**	**0.00%**

Total Vehicles	**2061**	**2623**	**4684**	**2305**	**2305**	**3535**	**3535**	**10524**	**100.00%**
Total PCU	**2877**	**3028**	**5905**	**3120**	**3120**	**4260**	**4260**	**13286**	
Directional Distribution	**19.6%**	**24.9%**	**44.5%**	**21.9%**	**21.9%**	**33.6%**	**33.6%**	**100.0%**	

Table 2-18: Summary of Evening Peak Hour Traffic at Town Hall Junction

Vehicles		D-1 to D-2	D-1 to D-3	Total Traffic from D-1	D-2 to D-3	Total Traffic from D-2	D-3 to D-2	Total Traffic from D-3	Total from All Directions	Composition of Vehicles
FAST MOVING VEHICLES	**2 Wheelers**	630	1042	**1672**	540	**540**	2430	**2430**	**4642**	47.58%
	Auto Rickshaw	311	420	**730**	291	**291**	628	**628**	**1650**	16.91%
	Car/Jeep/Van	364	687	**1051**	306	**306**	1143	**1143**	**2500**	25.62%
	Min-Bus	15	14	**29**	18	**18**	32	**32**	**79**	0.81%
	Std. Bus	112	78	**189**	117	**117**	170	**170**	**476**	4.88%
	LCV	91	65	**156**	59	**59**	107	**107**	**321**	3.29%
	2 Axle Trucks	12	14	**26**	20	**20**	39	**39**	**86**	0.88%
	3 Axle Trucks	0	0	**0**	0	**0**	0	**0**	**0**	0.00%
	MAVs	0	0	**0**	0	**0**	0	**0**	**0**	0.00%
	Tractor With Trailer	0	2	**2**	0	**0**	0	**0**	**2**	0.02%
	Tractor Without Trailer	0	0	**0**	0	**0**	0	**0**	**0**	0.00%

SLOW MOVING VEHICLES	Cycle	0	2	**2**	0	**0**	0	**0**	**2**	0.02%
	Bullock Cart	0	0	**0**	0	**0**	0	**0**	**0**	0.00%
	Horse Drawn Vehicle	0	0	**0**	0	**0**	0	**0**	**0**	0.00%
	Hand Drawn Vehicle	0	0	**0**	0	**0**	0	**0**	**0**	0.00%
Total Vehicles		**1534**	**2323**	**3858**	**1350**	**1350**	**4550**	**4550**	**9758**	**100.00%**
Total PCU		**2046**	**2745**	**4792**	**1877**	**1877**	**5131**	**5131**	**11800**	
Directional Distribution		**15.7%**	**23.8%**	**39.5%**	**13.8%**	**13.8%**	**46.6%**	**46.6%**	**100.0%**	

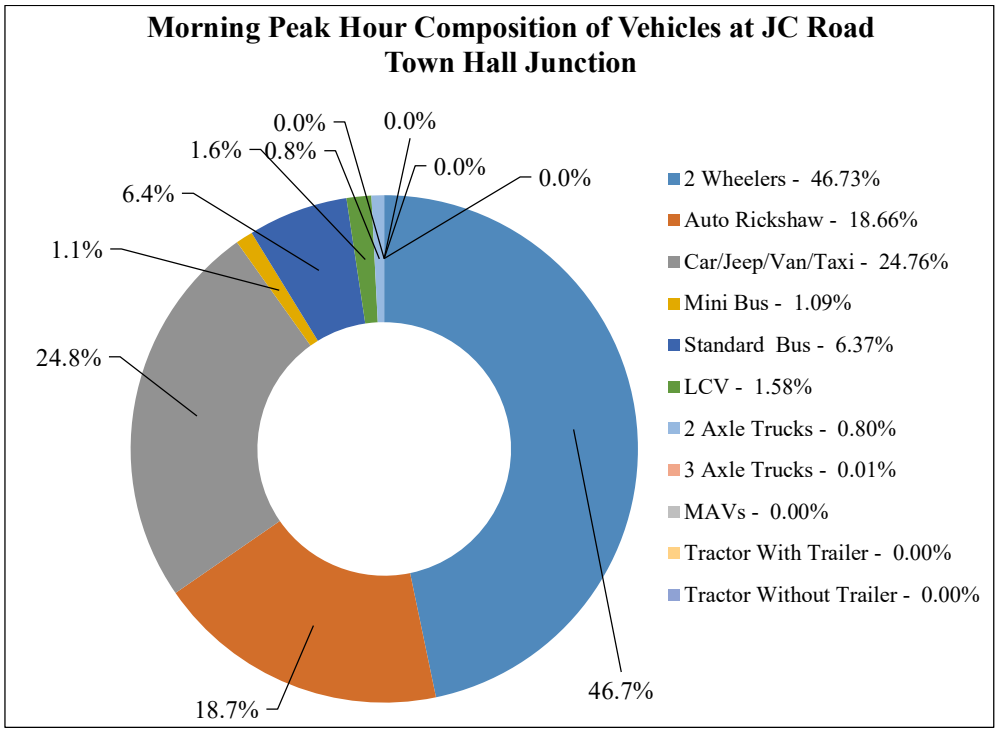


Figure 2-13: Morning Peak Hour Composition at Town Hall Junction

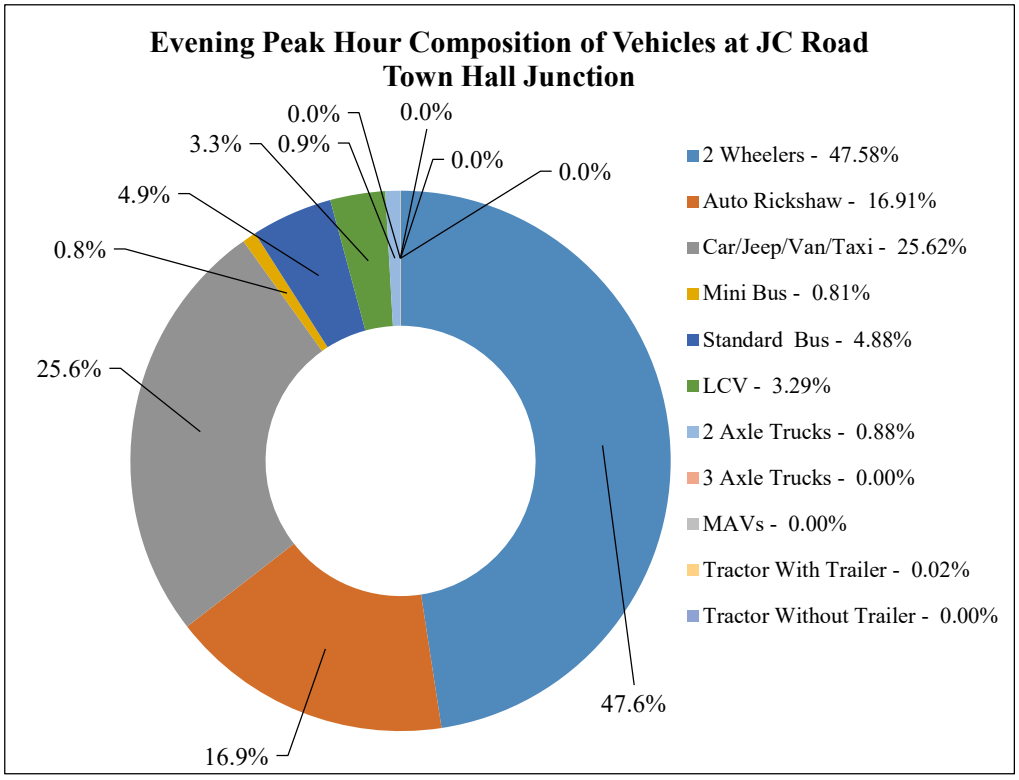


Figure 2-14: Evening Peak Hour Composition at Town Hall Junction

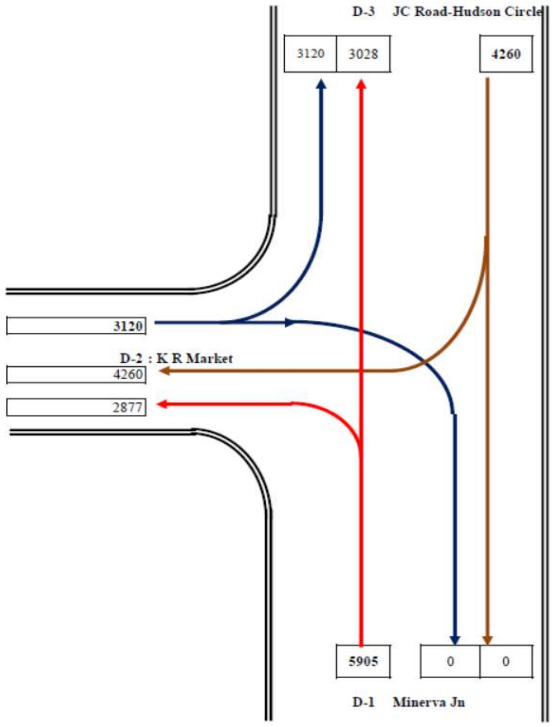


Figure 2-15: Morning Peak Hour Traffic Flow at Town Hall Junction

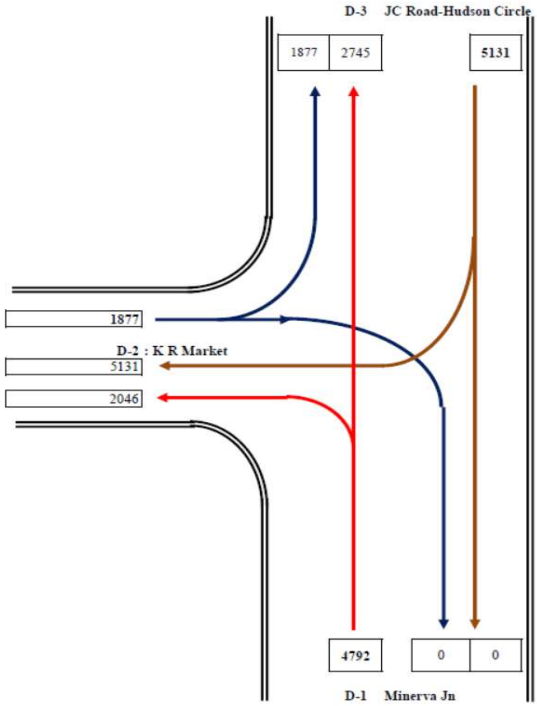


Figure 2-16: Evening Peak Hour Traffic Flow at Town Hall Junction

2.2.5 Badami House Junction (JC Road with SP Road and Mission Road)

Badami House Junction (JC Road with SP Road and Mission Road) Junction is a Four leg junction and presently has restricted directional movements at the junction. As per the present traffic flow, following are the directions allowed for traffic movement.

- Minerva Junction to Hudson Circle (JC Road)
- SP Road to (K R Market) to Hudson Circle (JC Road)
- SP Road to (K R Market) to Mission Road (Lalbagh Road)
- Hudson Circle to Nrupathunga Road (K R Market)
- Hudson Circle to Mission Road (Lalbagh Road)

Based on these traffic flow at the junction, the data collected for the three days has been averaged and summary of the data analysis are presented below for the junction.

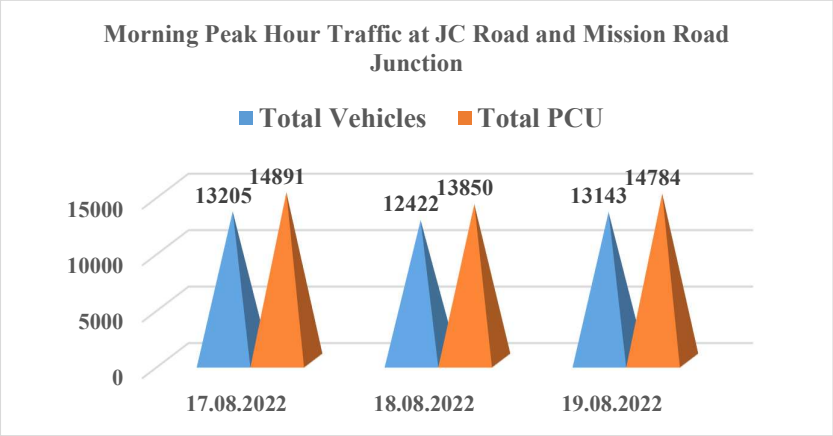
Summary of three days Morning Peak Hour and Evening Peak Hours are presented below.

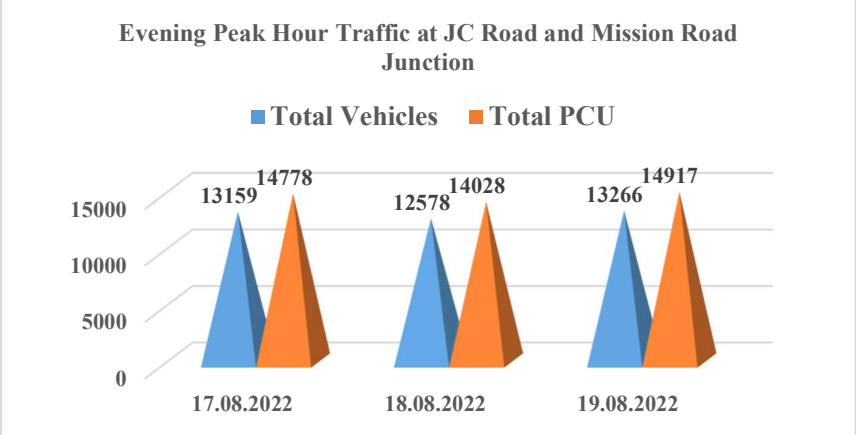
Table 2-19: 3 Days Morning Peak Hour Traffic at Badami House Junction (JC Road with SP Road and Mission Road)

Date	Peak Hour	Total Vehicles	Total PCU
17.08.2022	11.00am to 12.00pm	13205	14891
18.08.2022	11.00am to 12.00pm	12422	13850
19.08.2022	11.00am to 12.00pm	13143	14784
Average of 17.08.2022 to 19.08.2022	**11.00am to 12.00pm**	**12923**	**14508**

Table 2-20: 3 Days Evening Peak Hour Traffic at Badami House Junction (JC Road with SP Road and Mission Road)

Date	Peak Hour	Total Vehicles	Total PCU
17.08.2022	05.00pm to 06.00pm	13159	14778
18.08.2022	05.00pm to 06.00pm	12578	14028
19.08.2022	05.00pm to 06.00pm	13266	14917
Average of 17.08.2022 to 19.08.2022	**05.00pm to 06.00pm**	**13001**	**14574**





Detailed Peak hour traffic details including, directional flow, vehicle types, composition, percentage of directional flow are presented in both tables and graphical representation for ready reference below for both morning peak and evening peak hours.

Table 2-21: Summary of Morning Peak Hour Traffic at Badami House Junction (JC Road with SP Road and Mission Road)

Vehicles		D-1 to D-3	Total Traffic from D-1	D-2 to D-3	D-2 to D-4	Total Traffic from D-2	D-3 to D-1	D-3 to D-4	Total Traffic from D-3	Total from All Directions	Composition of Vehicles
FAST MOVING VEHICLES	2 Wheelers	2345	**2345**	931	1279	**2210**	1741	237	**1978**	**6533**	**50.55%**
	Auto Rickshaw	693	**693**	297	489	**786**	700	105	**805**	**2284**	**17.67%**
	Car/Jeep/Van	1348	**1348**	540	336	**876**	780	150	**930**	**3154**	**24.41%**
	Min-Bus	57	**57**	13	13	**27**	14	1	**15**	**99**	**0.76%**
	Std. Bus	276	**276**	5	56	**61**	134	115	**249**	**586**	**4.54%**
	LCV	28	**28**	20	52	**72**	46	8	**53**	**154**	**1.19%**
	2 Axle Trucks	36	**36**	18	15	**33**	28	1	**29**	**98**	**0.76%**
	3 Axle Trucks	0	**0**	0	2	**2**	2	0	**2**	**4**	**0.03%**
	MAVs	0	**0**	0	0	**0**	0	0	**0**	**0**	**0.00%**
	Tractor With Trailer	0	**0**	0	1	**1**	1	0	**1**	**2**	**0.02%**
	Tractor Without Trailer	0	**0**	0	0	**0**	0	0	**0**	**0**	**0.00%**
SLOW MOVING VEHICLES	Cycle	2	**2**	1	4	**5**	3	0	**3**	**10**	**0.07%**
	Bullock Cart	0	**0**	0	0	**0**	0	0	**0**	**0**	**0.00%**
	Horse Drawn Vehicle	0	**0**	0	0	**0**	0	0	**0**	**0**	**0.00%**
	Hand Drawn Vehicle	0	**0**	0	0	**0**	0	0	**0**	**0**	**0.00%**

Total Vehicles	**4785**	**4785**	**1824**	**2247**	**4072**	**3449**	**617**	**4066**	**12923**	**100.00%**
Total PCU	**5299**	**5299**	**1929**	**2535**	**4464**	**3939**	**807**	**4746**	**14508**	
Directional Distribution	**37.0%**	**37.0%**	**14.1%**	**17.4%**	**31.5%**	**26.7%**	**4.8%**	**31.5%**	**100.0%**	

Table 2-22: Summary of Evening Peak Hour Traffic at Badami House Junction (JC Road with SP Road and Mission Road)

Vehicles		D-1 to D-3	Total Traffic from D-1	D-2 to D-3	D-2 to D-4	Total Traffic from D-2	D-3 to D-1	D-3 to D-4	Total Traffic from D-3	Total from All Directions	Composition of Vehicles
FAST MOVING VEHICLES	**2 Wheelers**	1538	**1538**	974	1339	**2313**	2485	231	**2716**	**6567**	50.51%
	Auto Rickshaw	679	**679**	352	545	**897**	630	47	**677**	**2253**	17.33%
	Car/Jeep/Van	982	**982**	367	453	**820**	1145	128	**1273**	**3075**	23.65%
	Min-Bus	31	**31**	15	24	**39**	37	1	**38**	**108**	0.83%
	Std. Bus	180	**180**	12	38	**50**	157	132	**289**	**519**	3.99%
	LCV	127	**127**	36	71	**107**	99	7	**106**	**340**	2.62%
	2 Axle Trucks	41	**41**	17	11	**28**	46	2	**48**	**117**	0.90%
	3 Axle Trucks	0	**0**	6	0	**6**	3	0	**3**	**9**	0.07%
	MAVs	0	**0**	0	0	**0**	0	0	**0**	**0**	0.00%
	Tractor With Trailer	0	**0**	0	0	**0**	1	0	**1**	**1**	0.01%
	Tractor Without Trailer	0	**0**	0	0	**0**	0	0	**0**	**0**	0.00%

SLOW MOVING VEHICLES	Cycle	1	1	4	4	8	5	0	5	14	0.11%
	Bullock Cart	0	0	0	0	0	0	0	0	0	0.00%
	Horse Drawn Vehicle	0	0	0	0	0	0	0	0	0	0.00%
	Hand Drawn Vehicle	0	0	0	0	0	0	0	0	0	0.00%
Total Vehicles		**3581**	**3581**	**1782**	**2484**	**4266**	**4606**	**548**	**5154**	**13001**	**100.00%**
Total PCU		**4204**	**4204**	**1959**	**2789**	**4748**	**4921**	**701**	**5622**	**14574**	
Directional Distribution		**27.5%**	**27.5%**	**13.7%**	**19.1%**	**32.8%**	**35.4%**	**4.2%**	**39.6%**	**100.0%**	

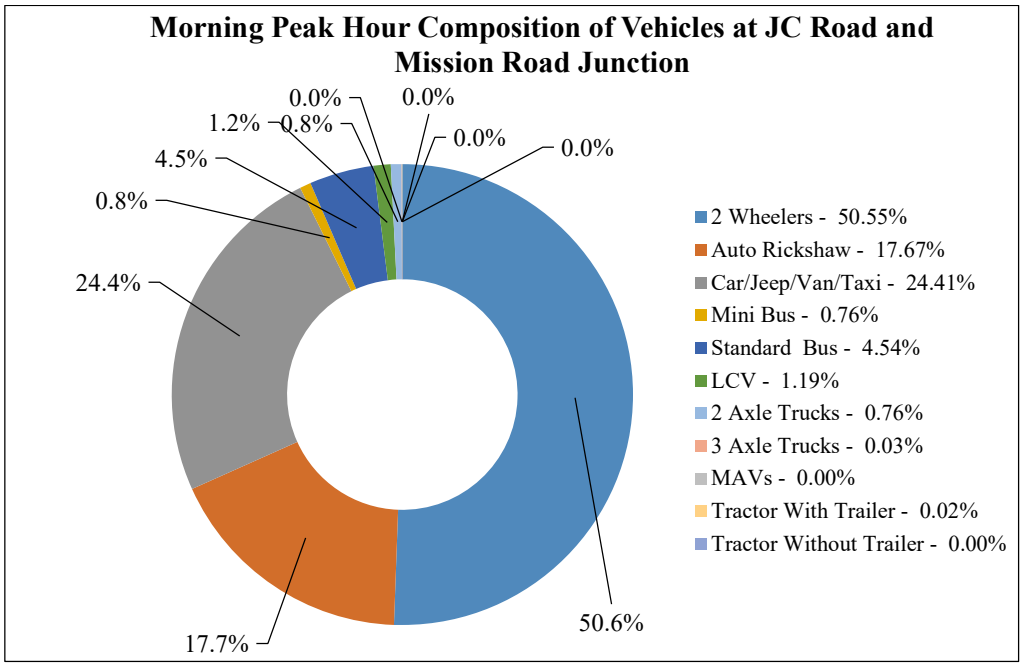


Figure 2-17: Morning Peak Hour Composition at Badami House Junction (JC Road with SP Road and Mission Road)

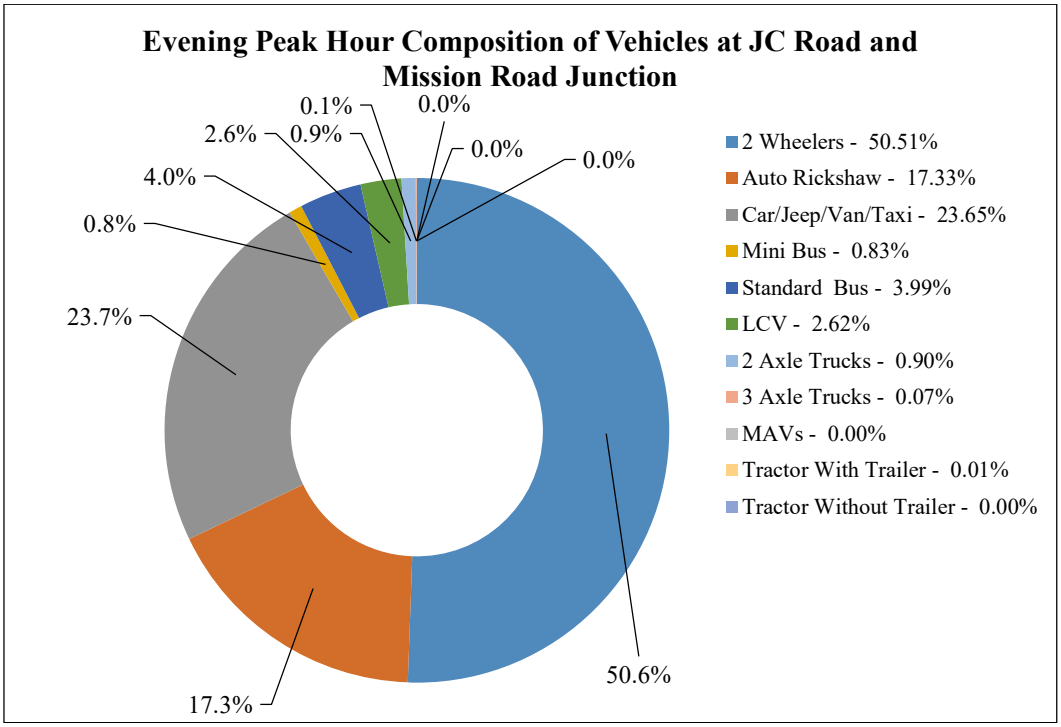


Figure 2-18: Evening Peak Hour Composition at Badami House Junction (JC Road with SP Road and Mission Road)

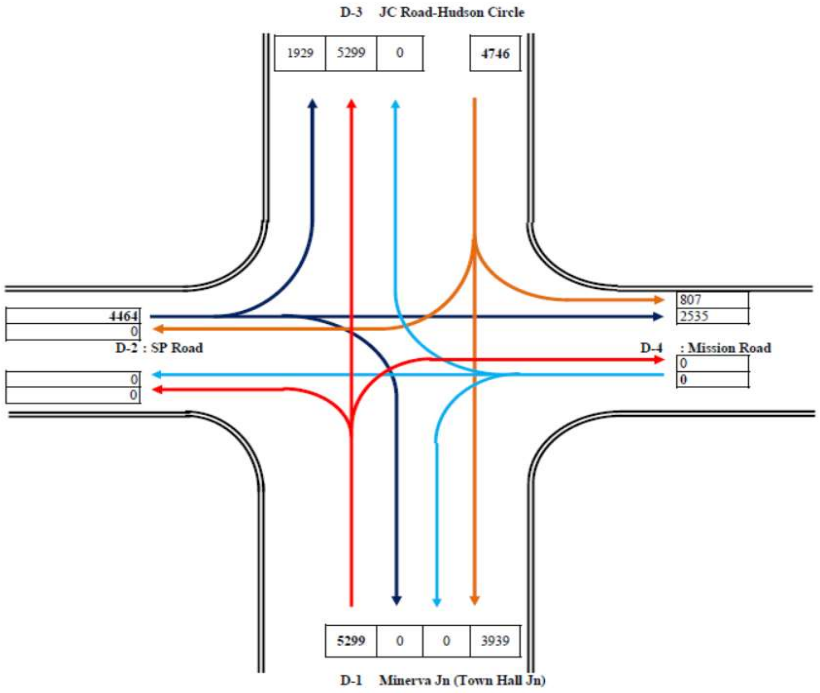


Figure 2-19: Morning Peak Hour Traffic Flow at Badami House Junction (JC Road with SP Road and Mission Road)

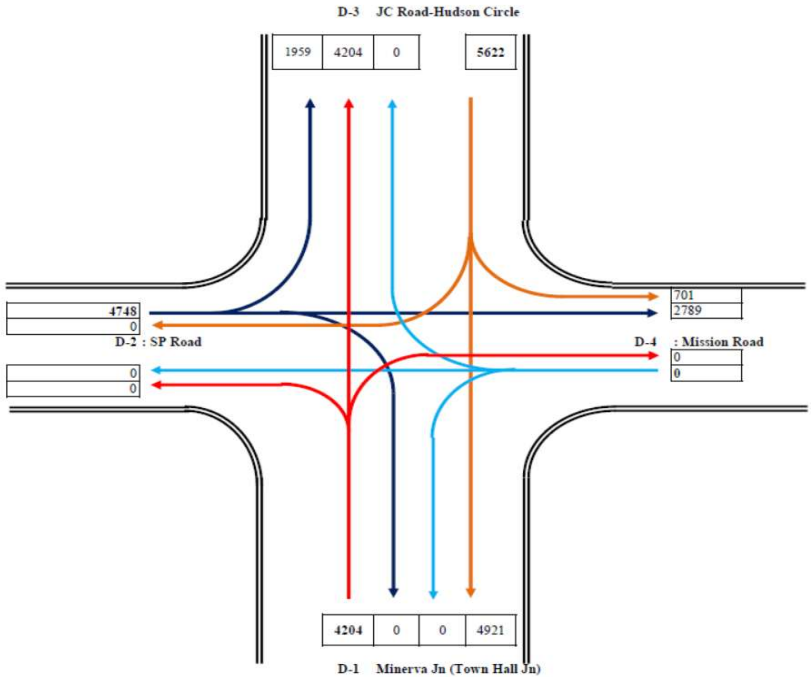


Figure 2-20: Evening Peak Hour Traffic Flow at Badami House Junction (JC Road with SP Road and Mission Road)

2.2.6 Halasur Gate Police Station Junction (JC Road with Naganna Road and Raja Ram Mohan Roy Road)

Halasur Gate Police Station Junction (JC Road with Naganna Road and Raja Ram Mohan Roy Road) is a Four leg junction and presently has restricted directional movements at the junction. As per the present traffic flow, following are the directions allowed for traffic movement.

- Minerva Junction (Town Hall) to Hudson Circle (KG Road / Kasturba Road)
- Naganna Road to Hudson Circle (KG Road / Kasturba Road)
- From Raja Ram Mohan Roy Road (BBMP Office) to Hudson Circle (KG Road / Kasturba Road)
- From Raja Ram Mohan Roy Road (BBMP Office) to Naganna Road

Based on these traffic flow at the junction, the data collected for the three days has been averaged and summary of the data analysis are presented below for the junction.

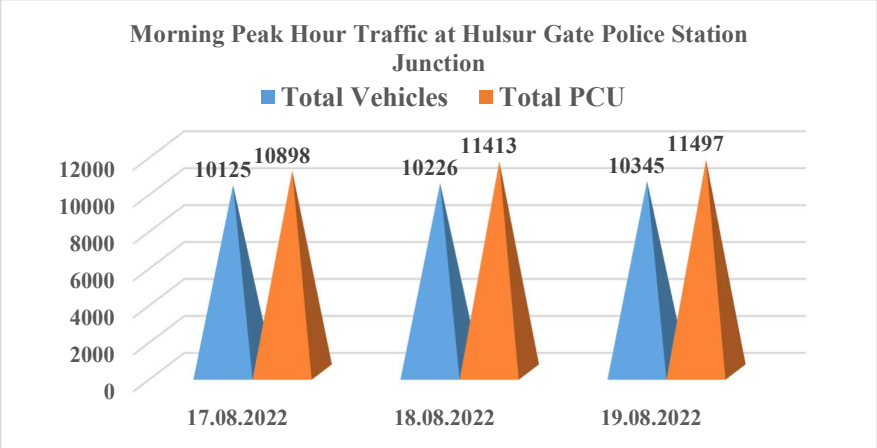
Summary of three days Morning Peak Hour and Evening Peak Hours are presented below.

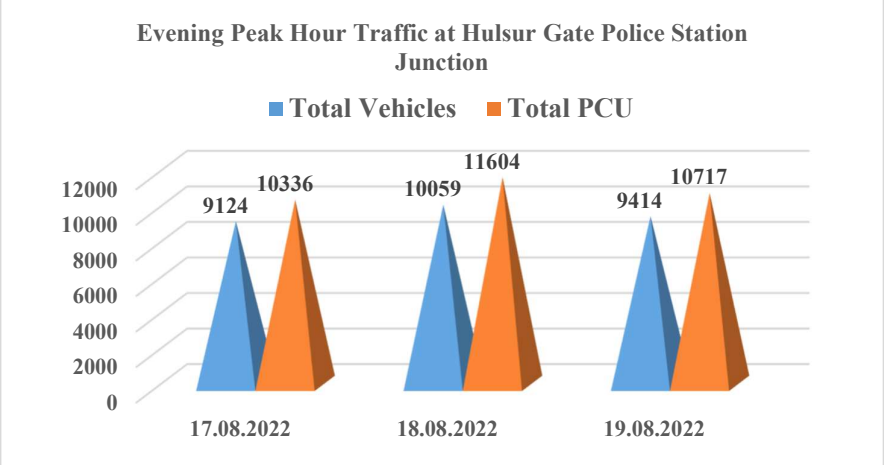
Table 2-23: 3 Days Morning Peak Hour Traffic at Halasur Gate Police Station Junction (JC Road with Naganna Road and Raja Ram Mohan Roy Road)

Date	Peak Hour	Total Vehicles	Total PCU
17.08.2022	09.00am to 10.00am	10125	10898
18.08.2022	11.00am to 12.00pm	10226	11413
19.08.2022	11.00am to 12.00pm	10345	11497
Average of 17.08.2022 to 19.08.2022	**11.00am to 12.00pm**	**10053**	**11198**

Table 2-24: 3 Days Evening Peak Hour Traffic at Halasur Gate Police Station Junction (JC Road with Naganna Road and Raja Ram Mohan Roy Road)

Date	Peak Hour	Total Vehicles	Total PCU
17.08.2022	04.00pm to 05.00pm	9124	10336
18.08.2022	04.00pm to 05.00pm	10059	11604
19.08.2022	04.00pm to 05.00pm	9414	10717
Average of 17.08.2022 to 19.08.2022	**04.00pm to 05.00pm**	**9532**	**10885**





Detailed Peak hour traffic details including, directional flow, vehicle types, composition, percentage of directional flow are presented in both tables and graphical representation for ready reference below for both morning peak and evening peak hours.

Table 2-25: Summary of Morning Peak Hour Traffic at Halasur Gate Police Station Junction (JC Road with Naganna Road and Raja Ram Mohan Roy Road)

Vehicles		D-1 to D-3	Total Traffic from D-1	D-2 to D-3	Total Traffic from D-2	D-4 to D-2	D-4 to D-3	Total Traffic from D-4	Total from All Directions	Composition of Vehicles
FAST MOVING VEHICLES	2 Wheelers	3314	**3314**	411	**411**	274	1093	**1368**	**5093**	**50.66%**
	Auto Rickshaw	1047	**1047**	97	**97**	105	378	**483**	**1626**	**16.18%**
	Car/Jeep/Van	1808	**1808**	38	**38**	59	568	**627**	**2473**	**24.60%**
	Min-Bus	99	**99**	0	**0**	2	30	**33**	**132**	**1.31%**
	Std. Bus	296	**296**	0	**0**	0	172	**172**	**469**	**4.66%**
	LCV	72	**72**	10	**10**	21	46	**67**	**150**	**1.49%**
	2 Axle Trucks	78	**78**	1	**1**	0	14	**14**	**93**	**0.93%**
	3 Axle Trucks	2	**2**	0	**0**	0	2	**2**	**4**	**0.04%**
	MAVs	0	**0**	0	**0**	0	0	**0**	**0**	**0.00%**
	Tractor With Trailer	0	**0**	0	**0**	0	0	**0**	**0**	**0.00%**
	Tractor Without Trailer	0	**0**	0	**0**	0	0	**0**	**0**	**0.00%**
SLOW MOVING VEHICLES	Cycle	2	**2**	2	**2**	9	0	**9**	**13**	**0.13%**
	Bullock Cart	0	**0**	0	**0**	0	0	**0**	**0**	**0.00%**
	Horse Drawn Vehicle	0	**0**	0	**0**	0	0	**0**	**0**	**0.00%**
	Hand Drawn Vehicle	0	**0**	0	**0**	0	0	**0**	**0**	**0.00%**

Total Vehicles	**6719**	**6719**	**560**	**560**	**470**	**2305**	**2775**	**10053**	**100.00%**
Total PCU	**7460**	**7460**	**558**	**558**	**511**	**2669**	**3180**	**11198**	
Directional Distribution	**66.8%**	**66.8%**	**5.6%**	**5.6%**	**4.7%**	**22.9%**	**27.6%**	**100.0%**	

Table 2-26: Summary of Evening Peak Hour Traffic at Halasur Gate Police Station Junction (JC Road with Naganna Road and Raja Ram Mohan Roy Road)

Vehicles		D-1 to D-3	Total Traffic from D-1	D-2 to D-3	Total Traffic from D-2	D-4 to D-2	D-4 to D-3	Total Traffic from D-4	Total from All Directions	Composition of Vehicles
FAST MOVING VEHICLES	**2 Wheelers**	2653	**2653**	449	**449**	321	1031	**1352**	**4454**	46.73%
	Auto Rickshaw	1210	**1210**	76	**76**	99	330	**429**	**1714**	17.98%
	(Yellow Board)	1782	**1782**	50	**50**	57	608	**665**	**2498**	26.20%
	Min-Bus	77	**77**	0	**0**	1	22	**23**	**100**	1.05%
	Std. Bus	259	**259**	0	**0**	0	173	**173**	**432**	4.53%
	LCV	109	**109**	7	**7**	18	108	**126**	**242**	2.54%
	2 Axle Trucks	54	**54**	1	**1**	0	15	**15**	**70**	0.73%
	3 Axle Trucks	4	**4**	0	**0**	0	3	**3**	**8**	0.08%
	MAVs	0	**0**	0	**0**	0	0	**0**	**0**	0.00%
	Tractor With Trailer	0	**0**	0	**0**	0	0	**0**	**0**	0.00%
	Tractor Without Trailer	0	**0**	0	**0**	0	0	**0**	**0**	0.00%
MOVING VEHICLES	**Cycle**	5	**5**	1	**1**	9	1	**9**	**15**	0.16%
	Bullock Cart	0	**0**	0	**0**	0	0	**0**	**0**	0.00%

	Horse Drawn Vehicle	0	**0**	0	**0**	0	0	**0**	**0**	0.00%
	Hand Drawn Vehicle	0	**0**	0	**0**	0	0	**0**	**0**	0.00%
Total Vehicles		**6154**	**6154**	**583**	**583**	**504**	**2291**	**2795**	**9532**	**100.00%**
Total PCU		**7160**	**7160**	**550**	**550**	**525**	**2650**	**3175**	**10885**	
Directional Distribution		**64.6%**	**64.6%**	**6.1%**	**6.1%**	**5.3%**	**24.0%**	**29.3%**	**100.0%**	

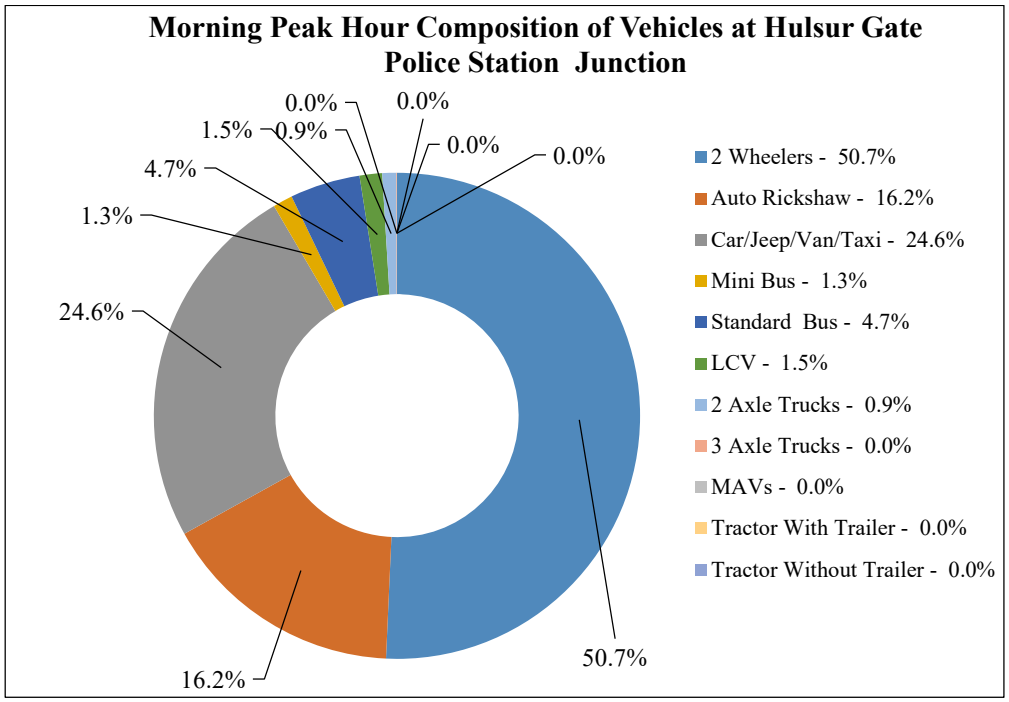


Figure 2-21: Morning Peak Hour Composition at Halasur Gate Police Station Junction (JC Road with Naganna Road and Raja Ram Mohan Roy Road)

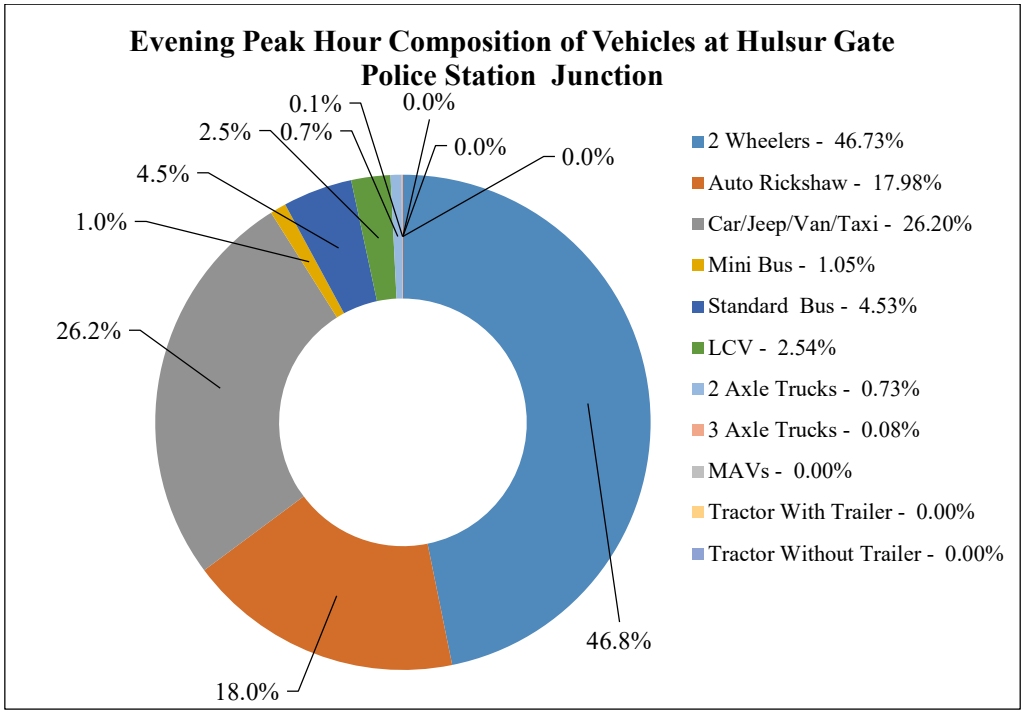


Figure 2-22: Evening Peak Hour Composition at Halasur Gate Police Station Junction (JC Road with Naganna Road and Raja Ram Mohan Roy Road)

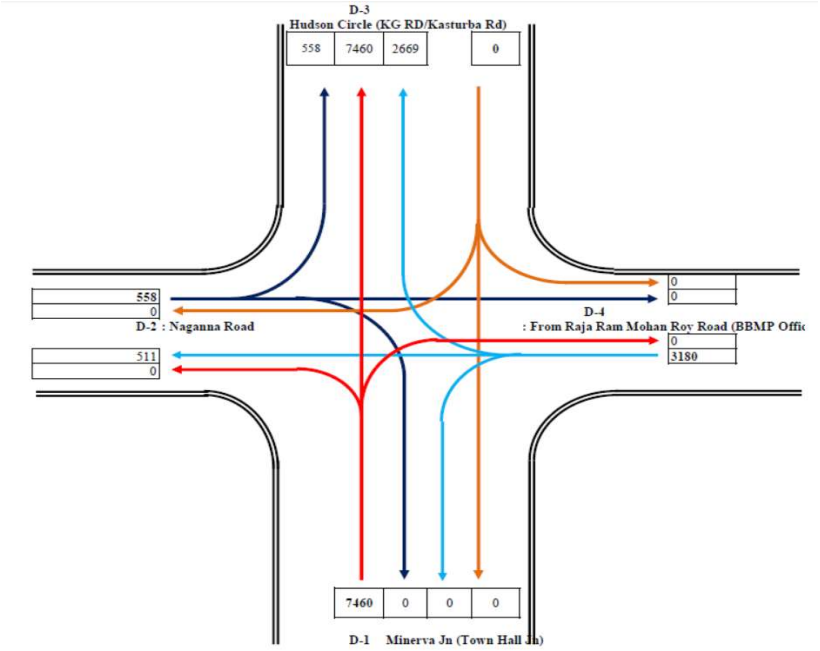


Figure 2-23: Morning Peak Hour Traffic Flow at Halasur Gate Police Station Junction (JC Road with Naganna Road and Raja Ram Mohan Roy Road)

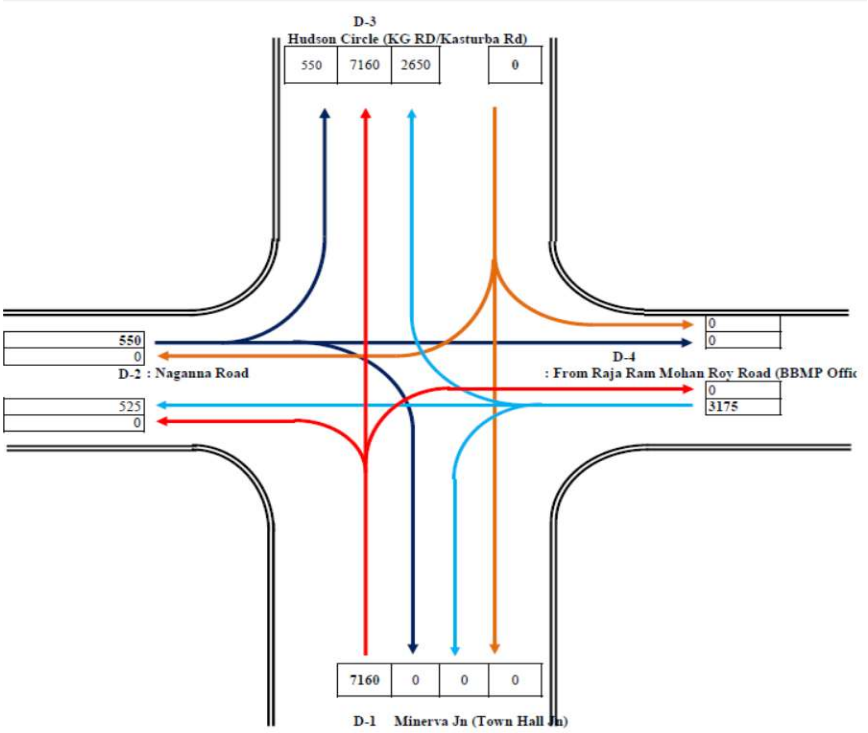


Figure 2-24: Evening Peak Hour Traffic Flow at Halasur Gate Police Station Junction (JC Road with Naganna Road and Raja Ram Mohan Roy Road)

2.2.7 Kempegowda Road (KG Road) Junction

Kempegowda Road (KG Road) Junction is a Four leg junction and presently has restricted directional movements at the junction. As per the present traffic flow, following are the directions allowed for traffic movement.

- Minerva Junction (Town Hall) to Kempegowda Road (KG Road)
- Minerva Junction (Town Hall) to Kasturba Road
- Nrupathunga Road to Kasthurba Road/Lalbagh Road/K R Market

Based on these traffic flow at the junction, the data collected for the three days has been averaged and summary of the data analysis are presented below for the junction.

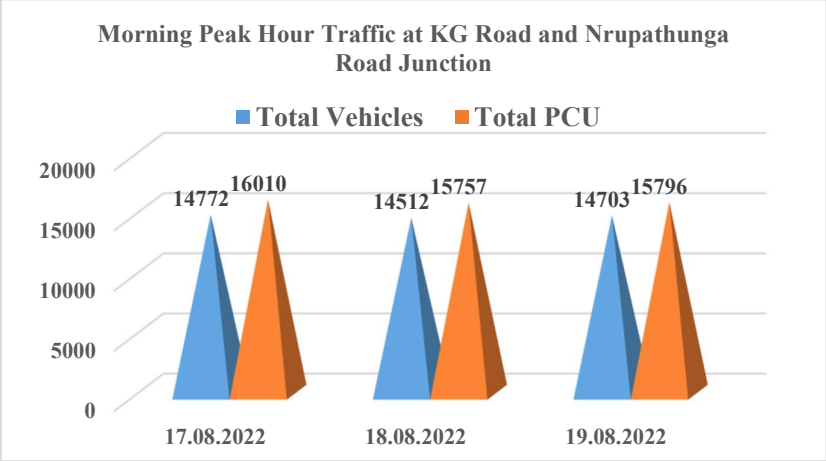
Summary of three days Morning Peak Hour and Evening Peak Hours are presented below.

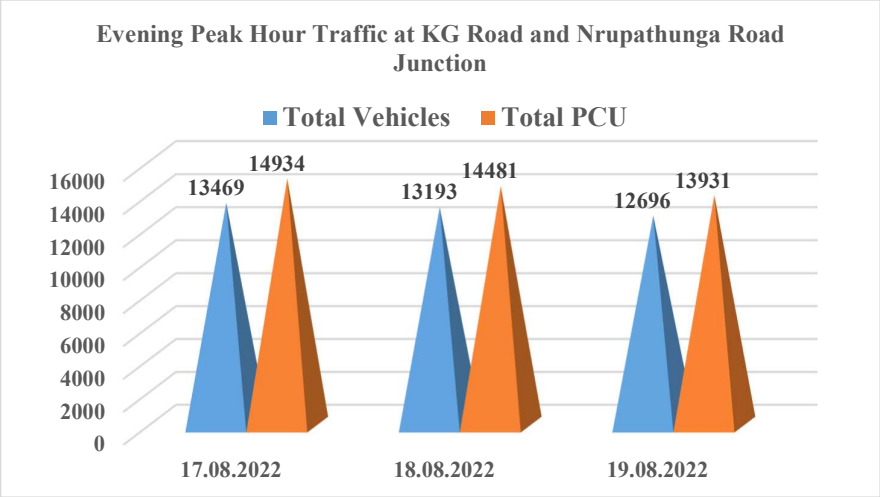
Table 2-27: 3 Days Morning Peak Hour Traffic at Kempegowda Road (KG Road) Junction

Date	Peak Hour	Total Vehicles	Total PCU
17.08.2022	09.00am to 10.00am	14772	16010
18.08.2022	09.00am to 10.00am	14512	15757
19.08.2022	09.00am to 10.00am	14703	15796
Average of 17.08.2022 to 19.08.2022	**09.00am to 10.00am**	**14662**	**15854**

Table 2-28: 3 Days Evening Peak Hour Traffic at Kempegowda Road (KG Road) Junction

Date	Peak Hour	Total Vehicles	Total PCU
17.08.2022	04.00pm to 05.00pm	13469	14934
18.08.2022	04.00pm to 05.00pm	13193	14481
19.08.2022	04.00pm to 05.00pm	12696	13931
Average of 17.08.2022 to 19.08.2022	**04.00pm to 05.00pm**	**13119**	**14449**





Detailed Peak hour traffic details including, directional flow, vehicle types, composition, percentage of directional flow are presented in both tables and graphical representation for ready reference below for both morning peak and evening peak hours.

Table 2-29: Summary of Morning Peak Hour Traffic at Kempegowda Road (KG Road) Junction Minerva Junction

Vehicles		D-1 to D-2	D-1 to D-4	Total Traffic from D-1	D-3 to D-4	Total Traffic from D-3	Total from All Directions	Composition of Vehicles
FAST MOVING VEHICLES	2 Wheelers	2360	2650	**5011**	2752	**2752**	**7762**	**52.94%**
	Auto Rickshaw	937	550	**1487**	558	**558**	**2045**	**13.95%**
	Car/Jeep/Van	1278	1038	**2316**	1380	**1380**	**3696**	**25.21%**

Vehicles		D-1 to D-2	D-1 to D-4	Total Traffic from D-1	D-3 to D-4	Total Traffic from D-3	Total from All Directions	Composition of Vehicles
	Min-Bus	48	30	**78**	19	**19**	**97**	**0.66%**
	Std. Bus	187	201	**388**	288	**288**	**676**	**4.61%**
	LCV	99	89	**188**	114	**114**	**302**	**2.06%**
	2 Axle Trucks	24	20	**43**	7	**7**	**51**	**0.35%**
	3 Axle Trucks	2	18	**20**	1	**1**	**21**	**0.14%**
	MAVs	0	0	**0**	0	**0**	**0**	**0.00%**
	Tractor With Trailer	0	0	**0**	1	**1**	**1**	**0.00%**
	Tractor Without Trailer	0	0	**0**	0	**0**	**0**	**0.00%**
SLOW MOVING VEHICLES	Cycle	6	5	**11**	1	**1**	**13**	**0.09%**
	Bullock Cart	0	0	**0**	0	**0**	**0**	**0.00%**
	Horse Drawn Vehicle	0	0	**0**	0	**0**	**0**	**0.00%**
	Hand Drawn Vehicle	0	0	**0**	0	**0**	**0**	**0.00%**
Total Vehicles		**4942**	**4601**	**9543**	**5119**	**5119**	**14662**	**100.00%**
Total PCU		**5604**	**4851**	**10455**	**5399**	**5399**	**15854**	
Directional Distribution		**33.7%**	**31.4%**	**65.1%**	**34.9%**	**34.9%**	**100.0%**	

Table 2-30: Summary of Evening Peak Hour Traffic at Kempegowda Road (KG Road) Junction Minerva Junction

Vehicles		D-1 to D-2	D-1 to D-4	Total Traffic from D-1	D-3 to D-4	Total Traffic from D-3	Total from All Directions	Composition of Vehicles
FAST MOVING VEHICLES	2 Wheelers	2161	1784	**3945**	2720	**2720**	**6665**	50.81%
	Auto Rickshaw	856	688	**1544**	542	**542**	**2086**	15.90%
	Car/Jeep/Van	1251	1053	**2304**	1028	**1028**	**3332**	25.40%
	Min-Bus	29	76	**105**	21	**21**	**126**	0.96%
	Std. Bus	246	77	**324**	196	**196**	**520**	3.96%

	LCV	143	48	**191**	105	**105**	**296**	2.26%
	2 Axle Trucks	31	19	**50**	18	**18**	**68**	0.52%
	3 Axle Trucks	5	6	**11**	1	**1**	**12**	0.09%
	MAVs	2	0	**2**	0	**0**	**2**	0.02%
	Tractor With Trailer	0	0	**0**	0	**0**	**0**	0.00%
	Tractor Without Trailer	0	0	**0**	0	**0**	**0**	0.00%
SLOW MOVING VEHICLES	**Cycle**	4	5	**9**	2	**2**	**11**	0.09%
	Bullock Cart	0	0	**0**	0	**0**	**0**	0.00%
	Horse Drawn Vehicle	0	0	**0**	0	**0**	**0**	0.00%
	Hand Drawn Vehicle	0	0	**0**	0	**0**	**0**	0.00%
Total Vehicles		**4729**	**3757**	**8486**	**4634**	**4634**	**13119**	**100.00%**
Total PCU		**5464**	**4178**	**9643**	**4806**	**4806**	**14449**	
Directional Distribution		**36.0%**	**28.6%**	**64.7%**	**35.3%**	**35.3%**	**100.0%**	

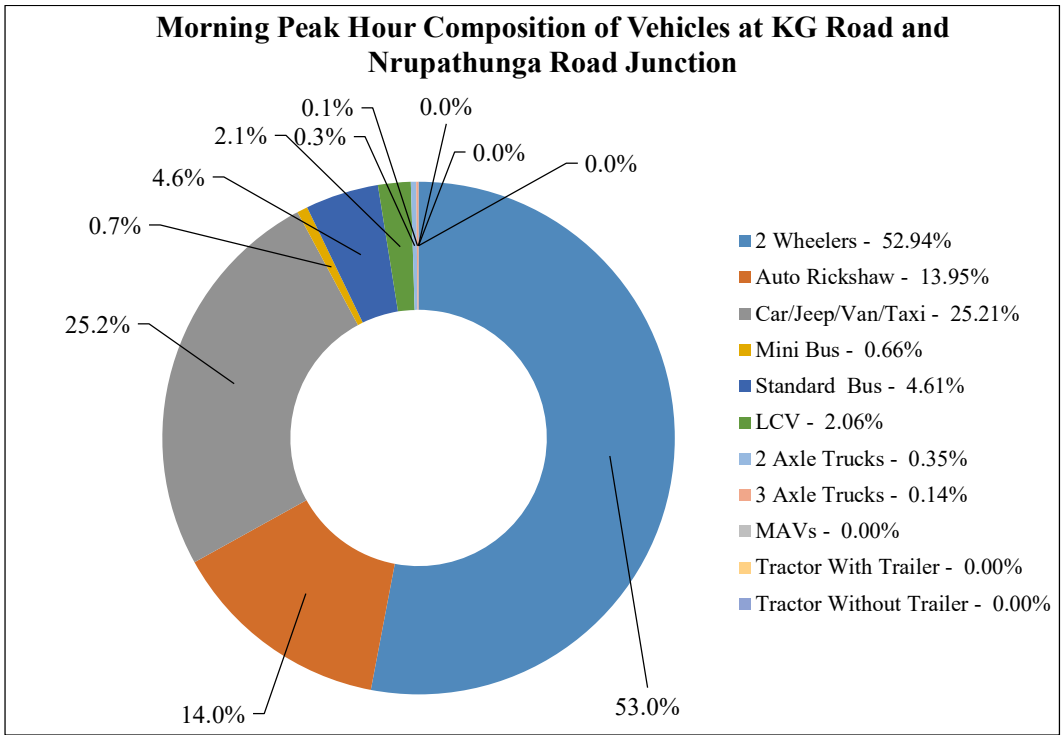


Figure 2-25: Morning Peak Hour Composition at Kempegowda Road (KG Road) Junction

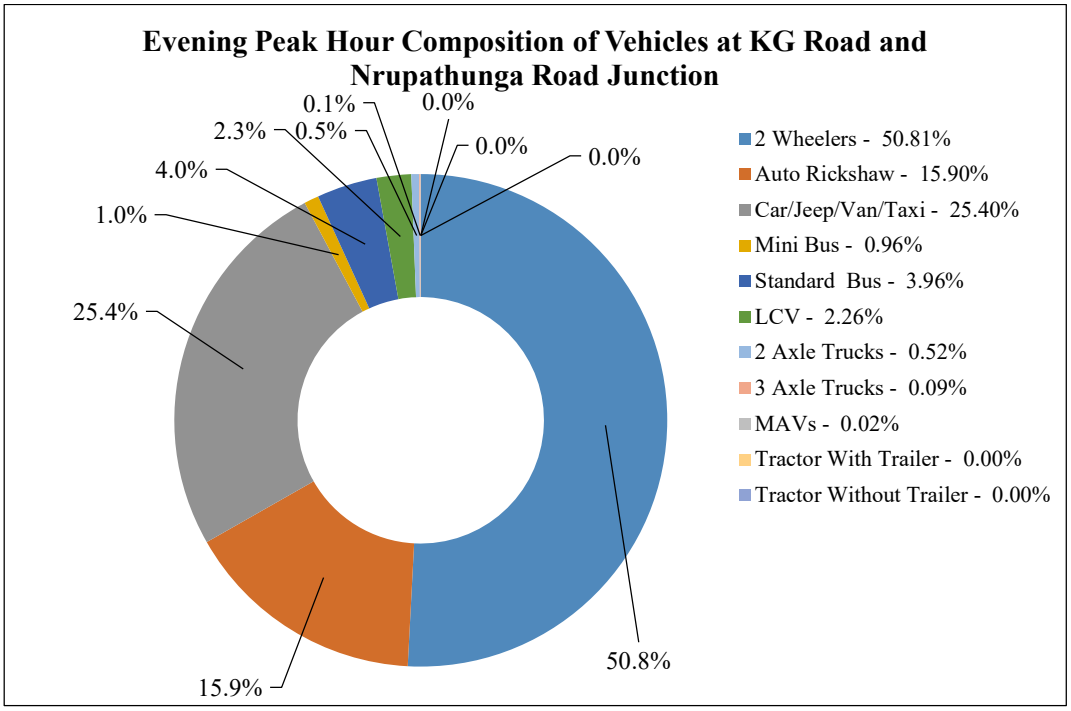


Figure 2-26: Evening Peak Hour Composition at Kempegowda Road (KG Road) Junction

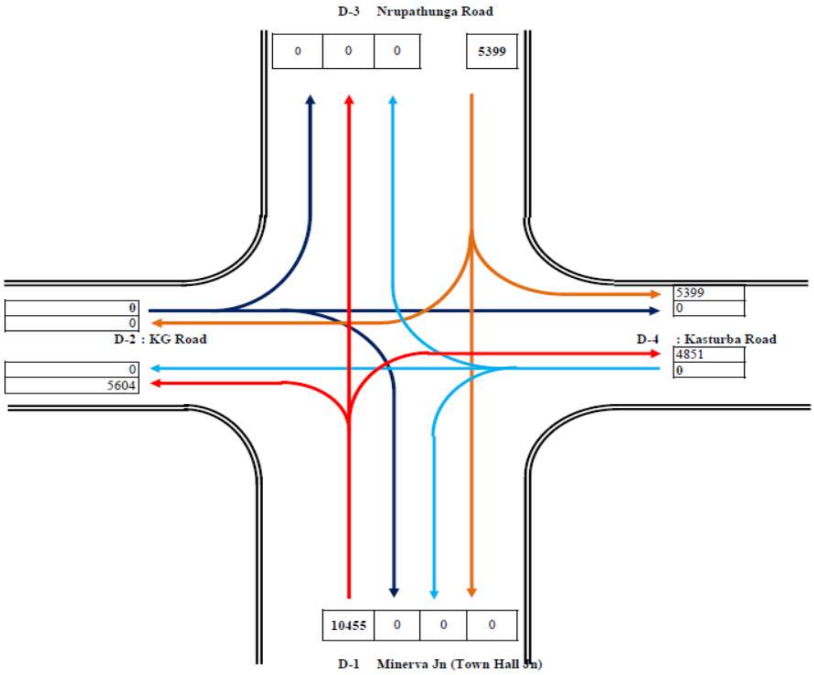


Figure 2-27: Morning Peak Hour Traffic Flow at Kempegowda Road (KG Road) Junction

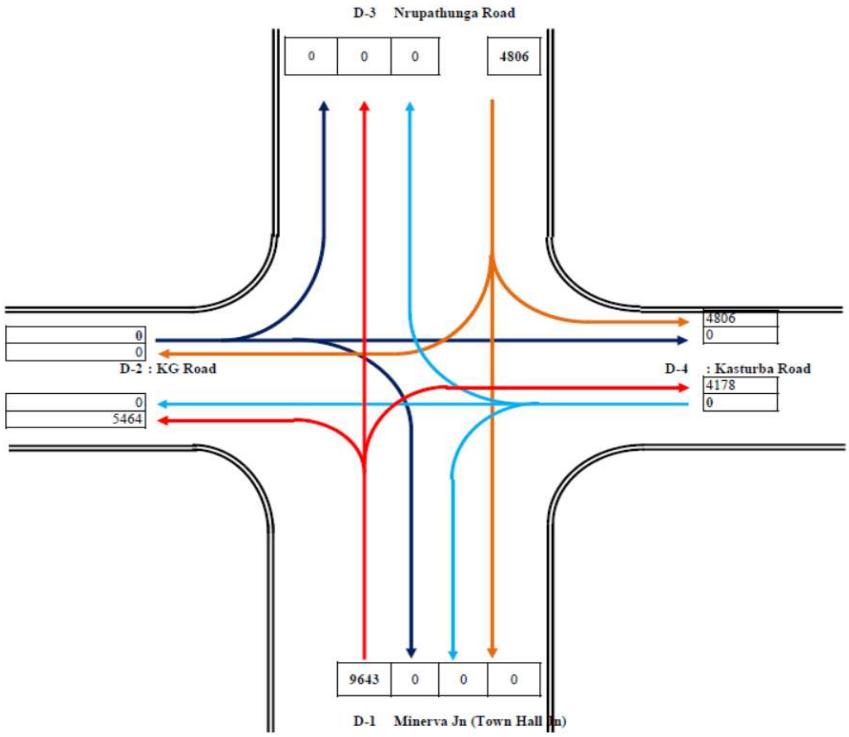


Figure 2-28: Evening Peak Hour Traffic Flow at Kempegowda Road (KG Road) Junction

2.2.8 NR Road & RRMR Road Junction

NR Road & RRMR Road Junction is a Four leg junction and presently has restricted directional movements at the junction. As per the present traffic flow, following are the directions allowed for traffic movement.

- Nrupathunga Road to Town Hall /Minerva Junction /K R Market/Lalbagh Road
- Nrupathunga Road to Devanga Hostel Road (to Mission Road)
- From Raja Ram Mohan Roy Road to Town Hall and KG Road

Based on these traffic flow at the junction, the data collected for the three days has been averaged and summary of the data analysis are presented below for the junction.

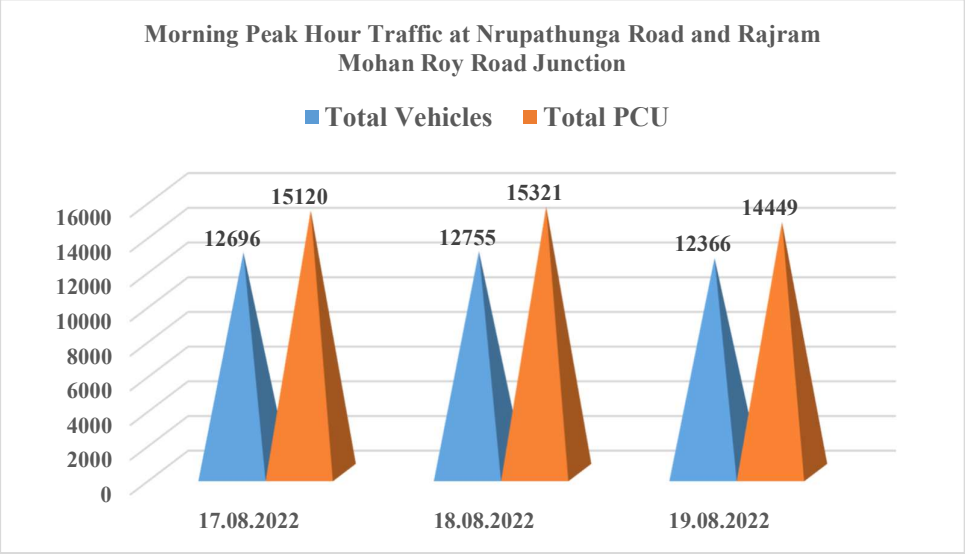
Summary of three days Morning Peak Hour and Evening Peak Hours are presented below.

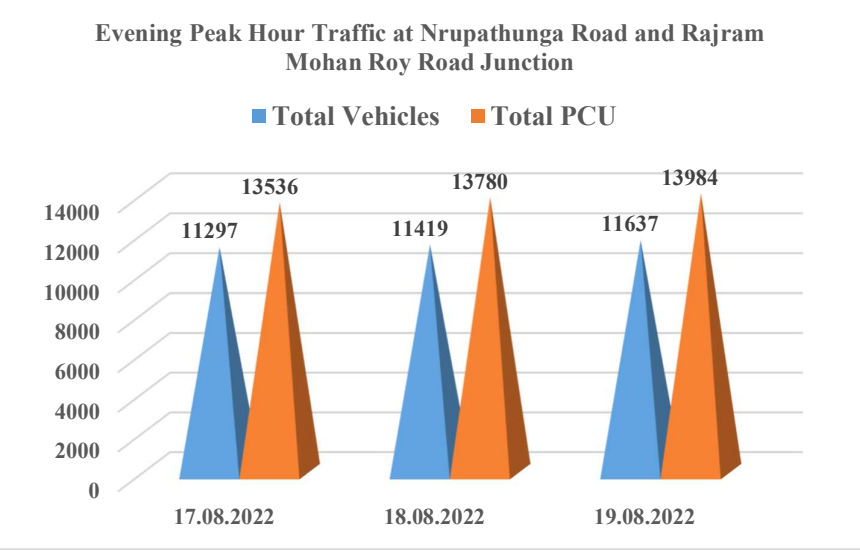
Table 2-31: 3 Days Morning Peak Hour Traffic at NR Road & RRMR Road Junction

Date	Peak Hour	Total Vehicles	Total PCU
17.08.2022	09.00am to 10.00am	12696	15120
18.08.2022	09.00am to 10.00am	12755	15321
19.08.2022	09.00am to 10.00am	12366	14449
Average of 17.08.2022 to 19.08.2022	**09.00am to 10.00am**	**12606**	**14964**

Table 2-32: 3 Days Evening Peak Hour Traffic at NR Road & RRMR Road Junction

Date	Peak Hour	Total Vehicles	Total PCU
17.08.2022	04.00pm to 05.00pm	11297	13536
18.08.2022	04.00pm to 05.00pm	11419	13780
19.08.2022	04.00pm to 05.00pm	11637	13984
Average of 17.08.2022 to 19.08.2022	**04.00pm to 05.00pm**	**11451**	**13767**





Detailed Peak hour traffic details including, directional flow, vehicle types, composition, percentage of directional flow are presented in both tables and graphical representation for ready reference below for both morning peak and evening peak hours.

Table 2-33: Summary of Morning Peak Hour Traffic at NR Road & RRMR Road Junction

Vehicles		D-2 to D-1	D-2 to D-4	Total Traffic from D-2	D-3 to D-1	Total Traffic from D-3	Total from All Directions	Composition of Vehicles
VIN G VE	2 Wheelers	1876	2119	**3995**	1866	**1866**	**5861**	**46.49%**

Vehicles		D-2 to D-1	D-2 to D-4	Total Traffic from D-2	D-3 to D-1	Total Traffic from D-3	Total from All Directions	Composition of Vehicles
	Auto Rickshaw	345	777	**1122**	629	**629**	**1751**	**13.89%**
	Car/Jeep/Van	2368	713	**3081**	802	**802**	**3883**	**30.80%**
	Min-Bus	47	10	**56**	21	**21**	**77**	**0.61%**
	Std. Bus	503	17	**520**	144	**144**	**664**	**5.27%**
	LCV	192	26	**218**	51	**51**	**269**	**2.13%**
	2 Axle Trucks	23	13	**36**	33	**33**	**70**	**0.55%**
	3 Axle Trucks	16	2	**18**	3	**3**	**21**	**0.16%**
	MAVs	0	0	**0**	0	**0**	**0**	**0.00%**
	Tractor With Trailer	0	0	**0**	0	**0**	**0**	**0.00%**
	Tractor Without Trailer	0	0	**0**	0	**0**	**0**	**0.00%**
SLOW MOVING VEHICLES	Cycle	6	1	**7**	2	**2**	**10**	**0.08%**
	Bullock Cart	0	0	**0**	0	**0**	**0**	**0.00%**
	Horse Drawn Vehicle	0	0	**0**	0	**0**	**0**	**0.00%**
	Hand Drawn Vehicle	0	0	**0**	0	**0**	**0**	**0.00%**
Total Vehicles		**5375**	**3678**	**9053**	**3552**	**3552**	**12606**	**100.00%**
Total PCU		**6777**	**4008**	**10784**	**4179**	**4179**	**14964**	
Directional Distribution		**42.6%**	**29.2%**	**71.8%**	**28.2%**	**28.2%**	**100.0%**	

Table 2-34: Summary of Evening Peak Hour Traffic at NR Road & RRMR Road Junction

Vehicles		D-2 to D-1	D-2 to D-4	Total Traffic from D-2	D-3 to D-1	Total Traffic from D-3	Total from All Directions	Composition of Vehicles
FAST MOVING VEHICLES	2 Wheelers	1973	1092	**3065**	1718	**1718**	**4783**	41.77%
	Auto Rickshaw	396	541	**937**	566	**566**	**1503**	13.12%
	Car/Jeep/Van	2222	700	**2922**	959	**959**	**3881**	33.89%
	Min-Bus	107	13	**120**	14	**14**	**134**	1.17%

	Std. Bus	390	6	**396**	200	**200**	**596**	5.20%
	LCV	187	56	**242**	178	**178**	**420**	3.67%
	2 Axle Trucks	41	17	**58**	52	**52**	**110**	0.96%
	3 Axle Trucks	10	2	**12**	3	**3**	**15**	0.13%
	MAVs	0	0	**0**	0	**0**	**0**	0.00%
	Tractor With Trailer	0	2	**2**	0	**0**	**2**	0.02%
	Tractor Without Trailer	0	0	**0**	0	**0**	**0**	0.00%
SLOW MOVING VEHICLES	**Cycle**	5	1	**6**	2	**2**	**8**	0.07%
	Bullock Cart	0	0	**0**	0	**0**	**0**	0.00%
	Horse Drawn Vehicle	0	0	**0**	0	**0**	**0**	0.00%
	Hand Drawn Vehicle	0	0	**0**	0	**0**	**0**	0.00%
Total Vehicles		**5329**	**2431**	**7760**	**3691**	**3691**	**11451**	**100.00%**
Total PCU		**6477**	**2775**	**9253**	**4514**	**4514**	**13767**	
Directional Distribution		**46.5%**	**21.2%**	**67.8%**	**32.2%**	**32.2%**	**100.0%**	

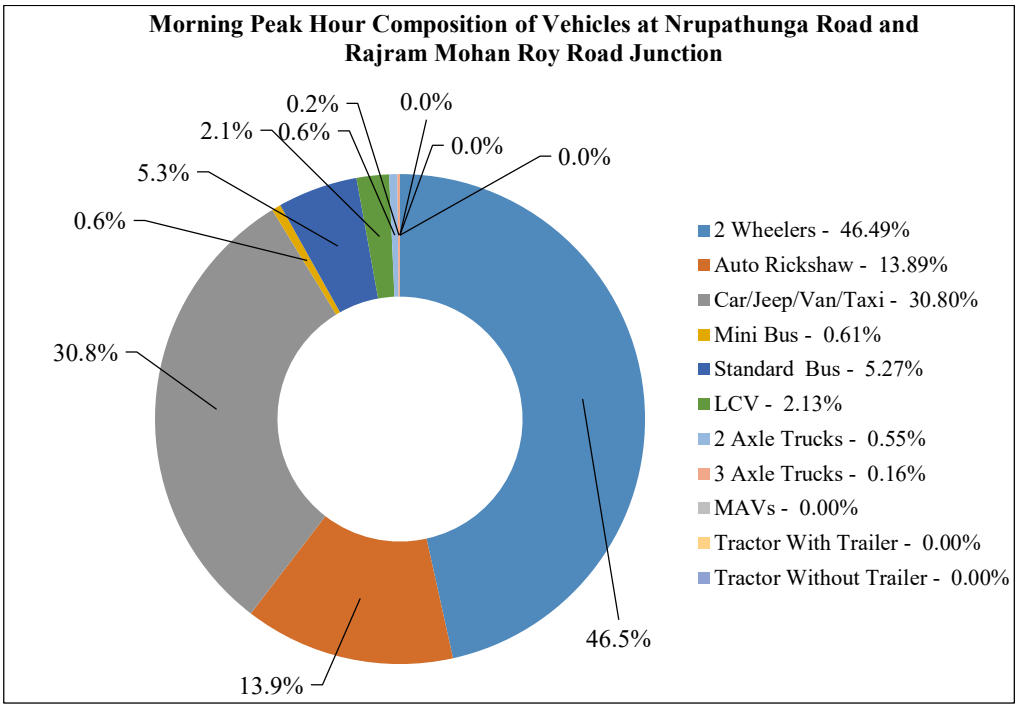


Figure 2-29: Morning Peak Hour Composition at NR Road & RRMR Road Junction

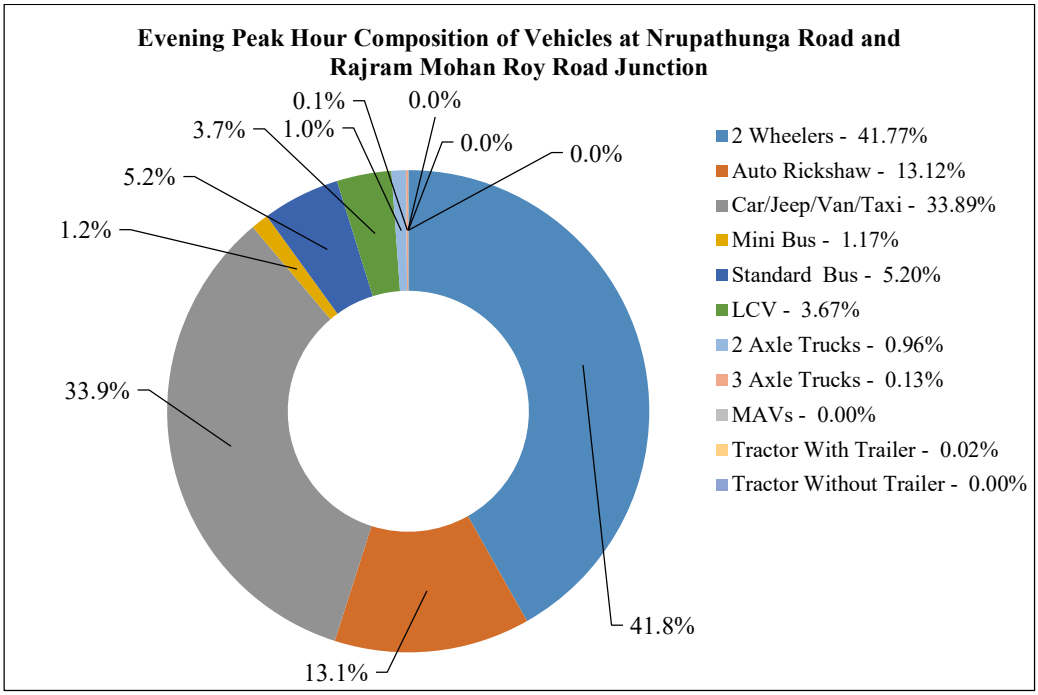


Figure 2-30: Evening Peak Hour Composition at NR Road & RRMR Road Junction

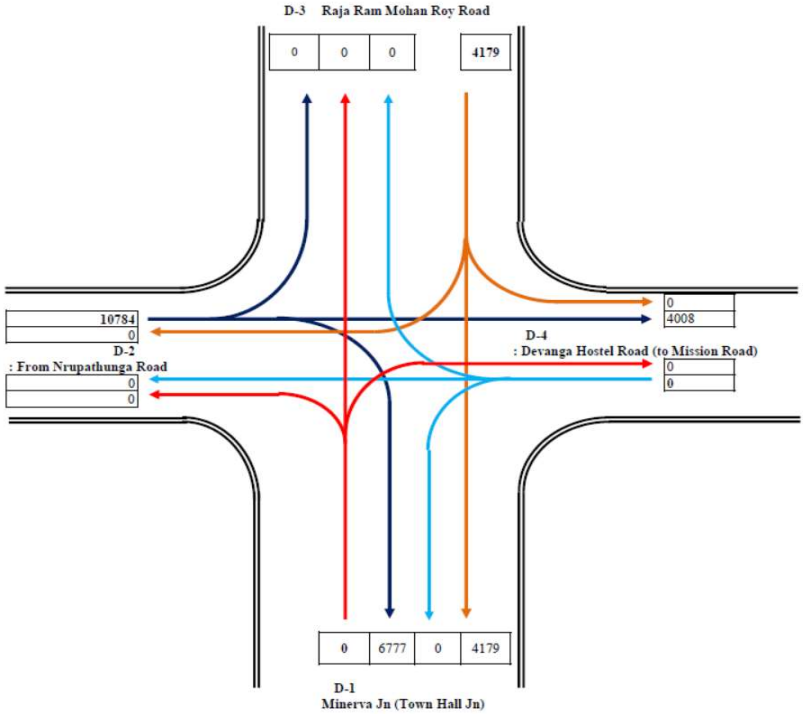


Figure 2-31: Morning Peak Hour Traffic Flow at NR Road & RRMR Road Junction

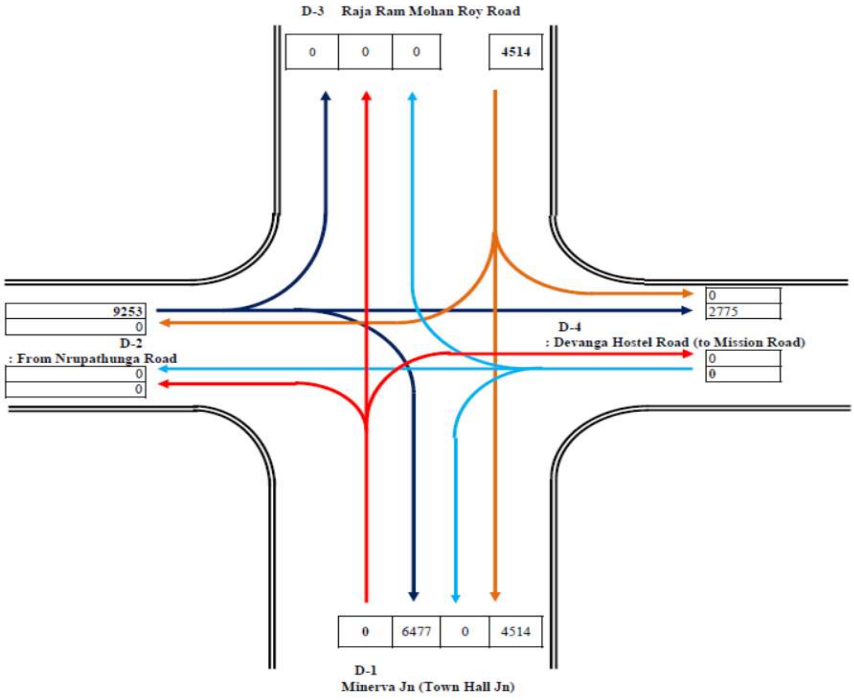


Figure 2-32: Evening Peak Hour Traffic Flow at NR Road & RRMR Road Junction

2.2.9 Present Peak Hour Traffic Flow from Minerva Junction to Hudson Circle

Summary of the present peak hour traffic at all the junctions for both Morning Peak as well as Evening Peak are presented below.

Table 2-35: Summary of Morning and Evening Peak Hour Traffic for all Junctions

No	Name of Junctions	Morning Peak Hour Traffic		Evening Peak Hour Traffic	
		Total Vehicles	Total PCU	Total Vehicles	Total PCU
1	**JUNCTION-1:** Minerva Junction	**12094**	**12760**	**9039**	**10455**
2	**JUNCTION-2:** JC Road with Armugum Mudaliar Road-Siddaiah Road Junction	**11050**	**11704**	**9911**	**10954**
3	**JUNCTION-3:** JC Road with Shivaji Talkies-Poornima Theatre Junction	**9608**	**10700**	**7561**	**8271**
4	**JUNCTION-4:** Town Hall Junction	**10524**	**13286**	**9758**	**11800**
5	**JUNCTION-5:** Badami House Junction	**12923**	**14508**	**13001**	**14574**
6	**JUNCTION-6:** Halasur Gate Police Station Junction	**10053**	**11198**	**9532**	**10885**
7	**JUNCTION-7:** Kempegowda Road (KG Road) Junction	**14662**	**15854**	**13119**	**14449**
8	**JUNCTION-8:** NR Road & RRMR Road Junction	**12606**	**14964**	**11451**	**13767**

Comparing the Morning and Evening Peak Hour traffic flow, morning peak hour is maximum for most of the locations. Hence, morning peak hour traffic details have been considered for further consideration and justification. Overall Morning Peak Hour traffic flow from Minerva Junction to Hudson Circle is presented below

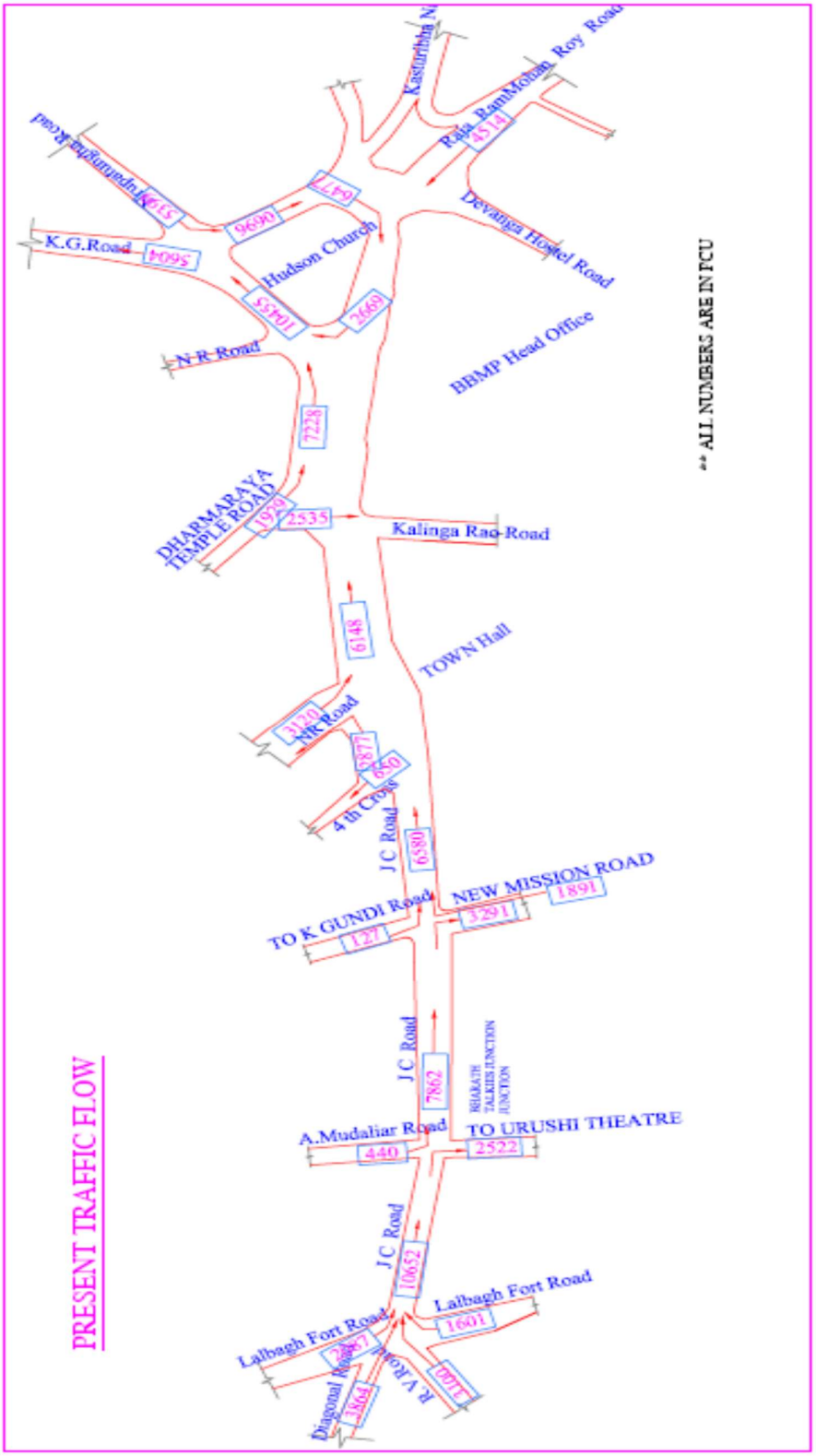

PRESENT TRAFFIC FLOW
** ALL NUMBERS ARE IN PCU
Kastaribha N
Raja RamMohan Roy Road
4514
Nrupathunga Road
5190
9690
647
K.G.Road
5604
Hudson Church
Devanga Hostel Road
10455
2669
N R Road
BBMP Head Office
7228
DHARMARAYA TEMPLE ROAD
1929
2535
Kalinga Rao Road
6148
TOWN Hall
3120
NR Road
2877
650
4 th Cross
J C Road
6580
NEW MISSION ROAD
1891
3291
TO K GUNDI Road
127
J C Road
7862
REHARATE TALKIES JUNCTION JUNCTION
A.Mudaliar Road
440
TO URUSHI THEATRE
2522
J C Road
10652
Lalbagh Fort Road
1601
Lalbagh Fort Road
2887
R V Road
3100
Diagonal Road
3864

Figure 2-33: Overall Morning Peak Hour Traffic Flow along JC Road

2.3 Necessity of Proposal for Grade Separators at Intersections/Junctions

As per IRC guidelines, the grade separator shall be proposed at the intersection locations to avoid any unnecessary delay to the traffic passing through the junction. Under such circumstances, as per the guidelines of stipulated under Section 4.5 of IRC-92-2017, the necessity of grade separator shall be examined for the following conditions as guiding principle conceptualising a traffic interchange.

(a) At all crossings of highway of the major hierarchy to be developed as fully access controlled.

(b) At all major crossings on highways to be developed to expressway standards.

(c) At the crossing of a major arterial road with another road of similar category carrying heavy traffic.

(d) When an at-grade intersection fails to cater the volume of traffic resulting in congestion and frequent blockage at the intersection e.g., when total traffic of all the arms of intersection exceeds 10,000 PCU per hour.

(e) High rate of fatal accidents at an at-grade intersection in spite of other traffic control or improvement measures.

(f) When the topography is such that interchange is the only alternative that can be constructed economically.

2.3.1 Justification of Elevated Road from Minerva Junction to Hudson Circle

- As per the peak hour traffic summary presented above, it is clearly evident that all the intersections under study have crossed traffic volume of **10,000 PCU per Hour** during **Morning Peak period.**
- Similarly, comparing the **Evening Peak Hour** traffic at all the junctions also have crossed the limit of **10,000 PCU per Hour** except one junction which is also close to this value during **Evening Peak Period**.

- Since, all these junctions are located closely to each other within a span of **2.20 Km** length, it is suggested to propose an **Elevated Road right from Minerva Junction to Hudson Circle** to facilitate the through traffic as well as local traffic.
- In addition to this, by proposing through elevated road between Minerva Junction and Hudson Circle will also facilitate traffic in opposite direction from **Hudson Circle to Minerva Junction** which is presently using the Krubigal Road (Lalbagh Road).
- With the proposal of elevated road, traffic from south to north bangalore and North to south bangalore will be through, resulting in relief for the 7 at grade junctions
- The main component of total traffic which are in the form of 2 wheelerrs, 4 wheelers and Autos are expected to use the elevated road there by improving the condition for movement of public transport at grade.

2.4 Origin – Destination Survey Data Analysis

A sample survey of Origin –Destination study was carried out at Minerva Junction (R V Road and Sajjan Rao Circle Road) and Hudson Circle (on Nrupathunga Road and Raj Ram Mohan Roy Road) in order to assess the travel pattern of the vehicles such as Four Wheelers and Two Wheelers using the JC road and Lallbagh Road respectively. A broad list of zone was considered for the purpose of analyzing the travel pattern or characteristics of the vehicles. The list of zones considered for the analysis are listed below.

Table 2-36: List of O-D Zones

Zone No.	Zone Details
1	Jayanagar, Banashankari, Kanakapura Road, J.P. Nagar, B.T.M.Layout
2	Kumaraswamy Layout, Uttarahalli, N.R.Colony, Basavanagudi, Srinagar, Hanumanthanagar, Bank Coloney, V.V.Puram
3	Mysore Road, K. R.Market, Chord Road, Vijayanagar, Chandra Layout, Kengeri, Chamarajapet.
4	Mejastic, Yeshwanthpura, Gandhinagara, Rajajinagar, Mathikere, Mahalakshmi Layout.
5	Malleshwaram, Hebbala, Sadashivanagar, R.T.Nagar, Bangalore Inernational

	Airport
6	Shivajinagar, M.G.Road, Ulsoor, Indiranagar, K. R. Puram, Maraathhalli, Whitefield.
7	Hudson Circle, Cubbon Park, Corporation, Vidhanasoudha.
8	Sarjapur Road, Koramangala, Madiwala, Elelctronics City Hosur Road.
9	Double Road, Wilson Garden, Audugodi, Lakkasandra.

2.4.1 O-D Data Analysis for RV Road and Sajjana Rao Circle Road (Diagonal Road) Traffic at Minerva Circle

- Origin-Destination sturdy was conducted by at Minerva Junction for the two arms i.e. RV Road and Sajjana Rao Circle.
- All the trips were categorized according to zones. O-D matrix has been developed based on the data collected.
- The collected data at Minerva Circle has been categorized based on each zone i.e. trip origin and their destination. The influence factors have been worked out to assess the potentiality of each zone in terms of trip generation and attraction. The influence factors for both Four Wheelers and Two Wheelers have been have been presented below.

Table 2-37: Influence Factors Based on O-D Survey at Minerva Circle

Zone No.	Influence Factors				Remarks
	R V Road		Sajjan Rao Circle Road		
	Four Wheelers	Two Wheelers	Four Wheelers	Two Wheelers	
1	34.49%	41.21%	15.26%	11.00%	Refer Note-1
2	15.51%	8.79%	33.17%	38.29%	
3	6.08%	6.40%	9.38%	12.22%	
4	5.46%	12.47%	6.61%	3.87%	Refer Note-2
5	8.06%	4.23%	15.38%	8.15%	
6	20.35%	16.05%	10.58%	12.02%	
7	4.71%	5.75%	6.49%	11.81%	
8	1.99%	1.52%	1.32%	0.61%	
9	3.35%	3.58%	1.80%	2.04%	
Total	**100.00%**	**100.00%**	**100.00%**	**100.00%**	

Note-1: *Zone 1 and Zone 2 are the Trip Origin Zones Prior to Minerva Junction.*

Note-2: *Zone 4, Zone 5, Zone 6 and Zone 7 are the Destination zones. The trips originated from Zone 1 and Zone 2 are bound to these Destination zones. Influence Factor for these zones works out to be* ***39% for Four Wheelers and 37% for Two Wheelers***

- From the above table it is observed that the traffic originating out of Zone 1 and 2 will get distributed on to other seven zones.
- Out of the remaining seven zones, zone no 4, 5, 6 and 7 will account for the through traffic between Minerva Circle to Hudson Circle and beyond Hudson circle.
- Zone no 3, 8 and 9 will account for the leakage of traffic between Minerva Circle and Hudson circle.
- From the above table, it is evident that, the zones except 3, 8 and 9 will account for more than 45 to 50% of the trips as per the influence factors from the zones located prior to Minerva Junction i.e. Zone 1 and Zone 2.
- Similarly, the zones located after Hudson Circle contributing to through trips on JC road from Minerva Junction towards Hudson circle and beyond Hudson circle which includes Zone 4, Zone 5, Zone 6 and Zone 7 with overall influence factors of these zones will account 35 to 40%.
- ***Therefore, for the purpose of assessment of through traffic on elevated road, 40% of the trips of both from 2-Wheelrs and Four Whelers entering JC Road from RV Road and Sajjana Rao Circle Road have been accounted for the proposed Elevated Road.***

2.4.2 O-D Analysis for Nrupathunga Road and Raja Ram Mohan Roy (RRMR) Road at Hudson Circle

Further, O-D study was also conducted on two roads approaching the Hudson circle i.e. on Nrupathunga Road and Raj Ram Mohan Roy Road to assess the traffic pattern which may use the JC road if a provision is made to use the proposed elevated road in two-way directional traffic movement.

The O-D data has been analysed for the collected data at Hudson Circle on two roads as mentioned above. The influence factors for zones have been calculated at this location for the two types of vehicles.

Table 2-38: Influence Factors Based on O-D Survey at Hudson Circle

Zone No.	Influence Factors				Remarks
	Nrupathunga Road		Rajaram Mohan Roy (RRMR) Road		
	Four Wheelers	Two Wheelers	Four Wheelers	Two Wheelers	
1	9.00%	8.50%	2.39%	3.32%	Refer Note-3
2	1.97%	1.05%	0.58%	0.57%	
3	20.51%	19.93%	15.30%	14.97%	
4	37.17%	35.94%	32.89%	31.75%	Refer Note-4
5	7.37%	7.73%	2.49%	1.24%	
6	5.17%	6.98%	22.81%	27.79%	
7	5.27%	7.33%	1.51%	2.71%	
8	10.18%	8.80%	17.88%	11.16%	Refer Note-3
9	3.36%	3.74%	4.14%	6.49%	
Total	**100.00%**	**100.00%**	**100.00%**	**100.00%**	

Note-3: *Zone 1, Zone 2, Zone 3, Zone 8 and Zone 9 are the Destination zones. The trips originated from Zone 4, Zone 5 and Zone 6 are bound to these destination zones. Influence Factor for these zones works out to be* ***43% for Four Wheelers and 40% for Two Wheelers.***

Note-4: *Zone 4, Zone 5, Zone 6 and Zone 7 are the Trip Origin Zones Prior to Hudson Circle.*

- From the above table it is observed that the traffic originating out of Zone 4, Zone 5, Zone 6 and Zone 7 will get distributed on to other seven zones.
- Out of the remaining five zones, Zone 1, Zone 2, Zone 3, Zone 8 and Zone 9 will account for the through traffic between Hudson Circle to Minerva Circle and beyond Minerva circle.
- Zone no 3, 8 and 9 will account for the leakage of traffic between Hudson circle to Minerva Circle.
- From the above table, it is evident that, the Zone 4, Zone 5, Zone 6 and Zone 7 will account for more than 55 to 60% of the trips as per the influence factors from the zones located prior to Hudson Circle i.e. Zone 4, Zone 5, Zone 6 and Zone 7.

- Similarly, the zones located after Minerva Junction contributing to through trips on JC road from Hudson Circle to Minerva Junction and beyond Minerva Junction which includes Zone 1, Zone 2, Zone 3, Zone 8 and Zone 9 with overall influence factors of these zones will account 40 to 45%.
- ***Therefore, for the purpose of assessment of through traffic on elevated road, 45% of the trips of both 2-Wheelrs and Four Whelers entering JC Road at Hudson Circle from Nrupathunga road as well as RRMR road have been accounted for the proposed Elevated Road in the opposite direction from Hudson Circle to Minerva Junction.***

2.5 Present Traffic on JC Road and Krumbigal Road (Lalbagh Road)

2.5.1 Present Traffic on JC Road from Minerva Junction to Hudson Circle

From the analysis, the traffic i.e. using JC road between Minerva Junction, Town Hall Junction and Hudson Circle is presented below. The traffic on the proposed road corridor is based on the maximum of the Peak hour traffic. It is observed that at almost all locations the maximum peak occurs in the morning peak period. Therefore, for the purpose of estimating the traffic for the corridor the morning peak hour traffic has been considered.

Table 2-39: Traffic on JC Road (From Minerva Junction to Hudson Circle)

Vehicles/Locations	Between Minerva Junction and AM Rd & Urvashi Theatre Road Junction	Between Urvashi Theatre Road Junction and Shivaji Theatre Junction before Town Hall Junction	Between Shivaji Theatre Junction and Town Hall Junction	Between Town Hall Junction & Badami House (SP Rd & Mission Rd) Junction	Between Badami House (SP Rd & Mission Rd) Junction & Halsur Gate Police Station Junction#	Between Halsur Gate Police Station Junction to KG Road & Kasturba Road Junction$
2 Wheelers	6325	4820	3431	2256	3276	5011
Auto Rickshaw	1634	1196	926	846	990	1487
Car/Jeep/Van	1947	1404	1396	1349	1888	2316

Vehicles/Locations	Between Minerva Junction and AM Rd & Urvashi Theatre Road Junction	Between Urvashi Theatre Road Junction and Shivaji Theatre Junction before Town Hall Junction	Between Shivaji Theatre Junction and Town Hall Junction	Between Town Hall Junction & Badami House (SP Rd & Mission Rd) Junction	Between Badami House (SP Rd & Mission Rd) Junction & Halsur Gate Police Station Junction#	Between Halsur Gate Police Station Junction to KG Road & Kasturba Road Junction$
Min-Bus	21	11	24	74	70	78
Std. Bus	212	96	197	310	281	388
LCV	96	92	135	49	48	188
2 Axle Trucks	23	22	33	44	54	43
3 Axle Trucks	2	11	4	0	0	20
MAVs	0	0	2	0	0	0
Tractor With Trailer	1	1	1	0	0	0
Tractor Without Trailer	0	0	0	0	0	0
Cycle	4	2	12	0	3	11
Bullock Cart	0	0	0	0	0	0
Horse Drawn Vehicle	0	0	0	0	0	0
Hand Drawn Vehicle	0	0	0	0	0	0
Total Vehicles	**10265**	**7654**	**6160**	**4928**	**6610**	**9543**
Total PCU	**10652**	**7862**	**6581**	**6149**	**7228**	**10455**

 # The traffic in this section includes the traffic coming from KR Market via Sharada Theatre and Traffic Coming from JC Road from Town Hall Junction to Hudson Circle.

$ The traffic in this section includes the traffic coming from KR Market via Sharada Theatre and Traffic Coming from JC Road from Town Hall Junction to Hudson Circle along with traffic from Rajaram Mohan Roy Road.

The vehicular compositions of traffic between the above locations are given in the Table below.

Table 2-40: Traffic Composition on JC Road form Minerva Circle to Hudson Circle

Vehicles/Locations	Between Minerva Junction and AM Rd & Urvashi Theatre Road Junction	Between Urvashi Theatre Road Junction and Shivaji Theatre Junction before Town Hall Junction	Between Shivaji Theatre Junction and Town Hall Junction	Between Town Hall Junction & Badami House (SP Rd & Mission Rd) Junction	Between Badami House (SP Rd & Mission Rd) Junction & Halsur Gate Police Station Junction	Between Halsur Gate Police Station Junction to KG Road & Kasturba Road Junction
2 Wheelers	61.6%	63.0%	55.7%	45.8%	49.6%	52.5%
Auto Rickshaw	15.9%	15.6%	15.0%	17.2%	15.0%	15.6%
Car/Jeep/Van	19.0%	18.3%	22.7%	27.4%	28.6%	24.3%
Min-Bus	0.2%	0.1%	0.4%	1.5%	1.1%	0.8%
Std. Bus	2.1%	1.3%	3.2%	6.3%	4.3%	4.1%
LCV	0.9%	1.2%	2.2%	1.0%	0.7%	2.0%
2 Axle Trucks	0.2%	0.3%	0.5%	0.9%	0.8%	0.5%
3 Axle Trucks	0.0%	0.1%	0.1%	0.0%	0.0%	0.2%
MAVs	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Tractor With Trailer	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Tractor Without Trailer	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Cycle	0.0%	0.0%	0.2%	0.0%	0.0%	0.1%
Bullock Cart	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Horse Drawn Vehicle	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Hand Drawn Vehicle	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Total Vehicles	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

The above table indicates that at all the sections of road, the two wheelers are the major contributors to the total traffic. Next forms the four wheelers traffic and the auto/three wheelers. All other traffic constitutes less than 6% of the total traffic. In order to assess the through traffic on the road between Minerva Junction and Hudson Circle traffic flow characteristics in terms of their directional movement is absolutely necessary which is done based on O-D Survey data analysis.

After reaching the Ulsoor Gate Police Station, the traffic gets bifurcated towards Kempegowda Road (towards Majestic) and Kasturba/Cubbon Park Roads at Hudson Circle. The details of the traffic on these two direction is presented below.

Table 2-41: Traffic Movement towards KG Road and Kasturba Road after Halasur Gate Police Station Junction

Vehicles	Halsur Gate Police Station Junction to KG Road	Halasur Gate Police Station Junction to Kasturba Road
2 Wheelers	2360	2650
Auto Rickshaw	937	550
Car/Jeep/Van	1278	1038
Min-Bus	48	30
Std. Bus	187	201
LCV	99	89
2 Axle Trucks	24	20
3 Axle Trucks	2	18
MAVs	0	0
Tractor With Trailer	0	0
Tractor Without Trailer	0	0
Cycle	6	5
Bullock Cart	0	0
Horse Drawn Vehicle	0	0
Hand Drawn Vehicle	0	0
Total Vehicles	**4942**	**4601**
Total PCU	**5604**	**4851**

2.5.2 Present Traffic Leading to Krumbigal Road (Lalbagh Road) from Hudson Circle

- The traffic leading to Lalbagh road (Krumbigal Road) from Nrupathunga Road and Rajaram Mohan Roy Road has been considered in order to assess the likely traffic that may use the proposed Elevated Road from Minerva Junction to Hudson Circle in the opposite direction i.e. from Hudson Circle to Minerva Junction.
- The elevated road is facilitating the two-way traffic at Hudson Circle enabling the traffic from Nrupathunga Road and Raja Ram Mohan Roy (RRMR) Road at Hudson Circle.
- The present traffic leading to Lalbagh road (Krumbigal Road) from Hudson Circle has been summarised based on the survey and presented in table below.
- This traffic volume will be factored based on the influence factor calculated based on the O-D survey data analysis and will arrive at the volume of traffic going to use the proposed elevated road from Hudson Circle to Minerva Junction in the subsequent section below.

Table 2-42: Traffic Movement from Nrupathunga Road towards Devanga Hostel Road (to link with Mission Road) and From Nrupathunga Road to Mission Road at Badami House Junction

Vehicles/Locations	From Nrupathunga Road towards Devanga Hostel Road (To Link with Mission Road) at Hudson Circle	From Nrupathunga Road towards Mission Road at Badami House Junction
2 Wheelers	2119	237
Auto Rickshaw	777	105
Car/Jeep/Van	713	150
Min-Bus	10	1
Std. Bus	17	115
LCV	26	8
2 Axle Trucks	13	1
3 Axle Trucks	2	0
MAVs	0	0
Tractor With Trailer	0	0
Tractor Without Trailer	0	0

Vehicles/Locations	From Nrupathunga Road towards Devanga Hostel Road (To Link with Mission Road) at Hudson Circle	From Nrupathunga Road towards Mission Road at Badami House Junction
Cycle	1	0
Bullock Cart	0	0
Horse Drawn Vehicle	0	0
Hand Drawn Vehicle	0	0
Total Vehicles	**3678**	**617**
Total PCU	**4008**	**807**

2.6 Estimated Traffic on Elevated Road Between Minerva Junction and Hudson Circle

2.6.1 Estimated Traffic on Elevated Road from Minerva Junction to Hudson Circle Direction

- The traffic at Minerva Junction from RV Road and Sajjan Rao Circle have been proposed to use the proposed elevated road from Minerva Junction to Hudson Circle.
- Therefore, the traffic from these two roads have been factored with percentage of through traffic based on the O-D analysis carried out for the present work and same is presented below.
- As per detail furnished above, the through traffic from these two roads for 2-wheelers and four wheelers has been estimated as **40% of the total traffic entering JC road from these two said roads as per the Influence Factors.** The same percentage has been considered for Auto/Three Wheelers also.
- However, for all other vehicles i.e. for Mini-Bus, Buses and all Goods Vehicles, it is presumed that around 20% of the corresponding category of vehicles may use the proposed elevated road. The following table indicates the expected ***traffic on Elevated Road from Minerva Junction to Hudson Circle Direction***.

Table 2-43: Estimated Traffic on Proposed Elevated Road from Minerva Junction to Hudson Circle Direction

Vehicles/Locations	Existing Traffic from RV Road	Existing Traffic from Sajjana Rao Circle	Total Traffic	Percentage of Through Traffic	Proposed Traffic on Elevated Road	Balance At-Grade Traffic from RV Road and Sajjan Rao Circle Road
2 Wheelers	1738	2862	**4600**	40%	1840	2760
Auto Rickshaw	502	480	**982**	40%	393	589
Car/Jeep/Van	706	684	**1390**	40%	556	834
Min-Bus	6	4	**10**	20%	2	8
Std. Bus	15	9	**24**	20%	5	19
LCV	18	24	**42**	20%	8	33
2 Axle Trucks	8	5	**13**	20%	3	10
3 Axle Trucks	1	0	**1**	20%	0	1
MAVs	0	0	**0**	20%	0	0
Tractor With Trailer	0	1	**1**	20%	0	1
Tractor Without Trailer	0	0	**0**	20%	0	0
Cycle	1	2	**3**		0	3
Bullock Cart	0	0	**0**		0	0
Horse Drawn Vehicle	0	0	**0**		0	0
Hand Drawn Vehicle	0	0	**0**		0	0
Total Vehicles	**2994**	**4070**	**7064**		**2807**	**4258**
Total PCU	**3100**	**3864**	**6964**		**2753**	**4211**

From the above table it is clear that, the number of lanes required along Minerva Junction to Hudson Circle is <u>3 Lanes</u> as on date considering LOS -C. for the present traffic

2.6.2 Estimated Traffic on Elevated Road from Hudson Circle to Minerva Junction Direction

- In addition to providing facility for the traffic from Minerva Junction to Hudson Circle, the traffic currently using Krumbigal Road (Lalbagh Road) to reach the Bangalore south areas beyond Minerva Junction through Devanga Hostel Road and Mission Road will be diverted to use the proposed elevated road from Minerva Junction to Hudson Circle in the opposite direction.
- By facilitating traffic movement on elevated road from Hudosn Circle to Minerva Junction, it would provide relief to the traffic on Krumbigal Road (Lalbagh Road).
- The traffic from Nrupathunga Road towards Devanga Hostel Road (to link with Mission Road) and from Raja Ram Mohan Roy Road /Nrupathunga Road to Mission Road at Badami House Junction have been factored with percentage of through traffic based on the O-D analysis and presented below.
- As per details furnished above, the through traffic from these two roads i.e. Nrupathunga Road and Raja Ram Mohan Roy Roads, the through traffic pertaining to 2-wheelers and four wheelers has been estimated as **45% of the total traffic entering Krumbigal Road via Devanga Hostel Road and Mission Road as per the Influence Factors**. The same percentage has been considered for Auto/Three Wheelers also.
- However, for all other vehicles i.e. for Mini-Bus, Buses and all Goods Vehicles, it is presumed that around 20% of the corresponding category of vehicles may use the proposed elevated road. The following table indicates the expected ***traffic on Elevated Road from Hudson Circle to Minerva Junction***.

Table 2-44: Estimated Traffic on Proposed Elevated Road from Hudson Circle to Minerva Junction

Vehicles/ Locations	From Nrupathunga Road towards Devanga Hostel Road (To Link with Mission Road) at Hudson Circle	From Nrupathunga Road towards Mission Road at Badami House Junction	Total Traffic to Krumbigal Road	% of Through Traffic	Proposed Traffic on Elevated Road - Hudson Circle to Minerva Junction	Balance At-Grade Traffic on Krumbigal Road (Lalbagh Road) from Hudson Circle
2 Wheelers	2119	237	**2356**	45%	1060	1296
Auto Rickshaw	777	105	**882**	15%	132	749
Car/Jeep/Van	713	150	**863**	45%	388	474
Min-Bus	10	1	**11**	20%	2	9
Std. Bus	17	115	**132**	20%	26	106
LCV	26	8	**34**	20%	7	27
2 Axle Trucks	13	1	**15**	20%	3	12
3 Axle Trucks	2	0	**2**	20%	0	2
MAVs	0	0	**0**	20%	0	0
Tractor With Trailer	0	0	**0**	20%	0	0
Tractor Without Trailer	0	0	**0**	20%	0	0
Cycle	1	0	**1**		0	1
Bullock Cart	0	0	**0**		0	0
Horse Drawn Vehicle	0	0	**0**		0	0
Hand Drawn Vehicle	0	0	**0**		0	0
Total Vehicles	**3678**	**617**	**4295**		**1619**	**2676**
Total PCU	**4008**	**807**	**4814**		**1527**	**3287**

From the above table it is clear that, the number of lanes required along Hudson Circle to Minerva Junction is <u>2 Lanes</u> as on date.

2.7 Traffic Projections

Generally, the facilities planned for facilitating of smooth flow of traffic both in urban and rural areas will be planned not only for present but also for future time horizon. In order to plan such facility, it is required to project the current traffic to certain time period say for about 20 years or 30 years.

- The data published by Transport Department, GoK in their Website has been compiled to estimate the growth of registered vehicles in Bangalore Metropolitan area.
- For the purpose of assessing the future traffic growth rates, the vehicles **(2 Wheelers and Four Wheelers)** registered in Bangalore Metropolitan area have been analysed from 2015 to 2022.
- In addition to these two vehicle types, the growth of registered all vehicles has also been analysed.

Table 2-45: Registered Vehicles Growth in Bangalore Metropolitan Area (2015-2022)

Sl. No.	Year	Total No. of Vehicles Registered as on		
		Two Wheelers	Cars	All Vehicles
1	31.03.2015	3841139	1088587	5559730
2	31.03.2016	4222676	1191541	6112897
3	31.03.2017	4731159	1321815	6833080
4	31.03.2018	5134055	1432374	7406202
5	31.03.2019	5588029	1541017	8049891
6	31.03.2020	6418232	1989509	9638362
7	31.03.2021	6673856	2085384	10010588
8	31.03.2022	6931839	2197158	10409289
	Average Growth, %	**11.49%**	**14.55%**	**12.46%**

- ***From the above, it is clear that the general traffic growth of all vehicles is about 12.46% for the last 8 years from 2015 to 2022.***
- ***This indicates that, the traffic has also increased at the same rate and will continue to grow at the same rate more or less.***
- ***In the event, if the present traffic expected on elevated road as well as on the at grade level on JC road are projected with above growth rate, then the requirement of lanes will be very high.***

2.8 Capacity Analysis and Lane Requirement between Minerva Junction and Hudson Circle

- As per the road inventory it is observed that, the JC road is having a varying carriageway width between three to four lane configurations.
- Basically the urban roads will be designed for Level of Service C (LOS C). As per IRC-106-1990, the capacity of 2-lane (one-way) is 2400PCU/hour.
- Since the traffic on the JC road is one-way and width of carriageway is almost 3 to 4-lane configurations from Minerva Junction to Town Hall Junction and Badami House Junction to Hudson Circle, therefore, the capacity of 3-lane (one-way) shall be 3600PCU/hour as per IRC-106-1990.
- Similarly, width of carriageway is 2-lane configurations from Town Hall Junction to Badami House Junction, the capacity of 2-lane (one-way) shall be 2400PCU/hour as per IRC-106-1990.

Hence, assuming Level of Service LOS-C and as per IRC guidelines, the Volume to Capacity Ratio between Minerva Junction and Hudson Circle is presented below for both conditions i.e. **Prior to implementation** of elevated road and **Post Implementation** of Elevated Road for the At-Grade Road (JC Road from Minerva Junction to Hudson Circle.

Theoretically, considering growth rate of vehicles as 10% and projecting traffic considering 20years, the traffic on elevated road would be 18520 and as per IRC standard growth rate of 5%, 7304 PCU which requires more than 6 lanes for one direction. Similarly for other direction it requires 4 lane with growth rate of 5%.

Considering the site constraints w.r.t available right of way and considering the fact that elevated road traffic comprises only 2 wheelers and four wheelers. The growth rate depends on the improvement in the public transport system. Presently Metro proposals are extending in different phases for different parts of the city, with the implementation of the Metro and other facilities of public transport system, there will be reduction in the use of 2wheelers and 4 wheelers by public. In view of the above points and site constraints 4 lane divided carriageway

elevated road is proposed considering present day traffic and with the proposed facility, there will be relief up to 56% in the main corridor under discussion.

Table 2-46 presents the comparison of present, future volume to capacity ratio at grade with the proposed 4 lane elevated corridor with % of relief to the grade level traffic.

Table 2-46: Present Volume to Capacity Ratio on JC Road (At Grade) from Minerva Junction to Hudson Circle for before and after Elevated Road

Vehicles/ Locations	Between Minerva Junction and AM Rd & Urvashi Theatre Road Junction	Between Urvashi Theatre Road Junction and Shivaji Theatre Junction before Town Hall Junction	Between Shivaji Theatre Junction and Town Hall Junction	Between Town Hall Junction & Badami House (SP Rd & Mission Rd) Junction	Between Badami House (SP Rd & Mission Rd) Junction & Halsur Gate Police Station Junction	Between Halasur Gate Police Station Junction to KG Road & Kasturba Road Junction
At Grade Present Peak Hour Traffic in PCU **without Elevated Road**	10652	7862	6581	6149	7228	10455
Average No of Lanes	4	4	4	2	3	3
Design Service Volume as per IRC-106-1990	3600*	3600*	3600*	2400	3600	3600
At Grade Road V/C Ratio without Elevated Road	**2.96**	**2.18**	**1.83**	**2.56**	**2.01**	**2.90**
At Grade Peak Hour Traffic in PCU **with**	7899	5109	3828	2931	4475	7702

Elevated Road						
Average No of Lanes	4	4	4	2	3	3
Design Service Volume as per IRC-106-1990	4800**	4800**	4800**	2400	3600	3600
At Grade Road V/C Ratio with Elevated Road	**1.65**	**1.06**	**0.80**	**1.22**	**1.24**	**2.14**
Percentage of Relief for At Grade Traffic due to Elevated Road	**44.25%**	**51.37%**	**56.28%**	**52.34%**	**38.09%**	**26.34%**

*3600 capacity is considered as it is 4 lanes without any medians

** 4800 Capacity is considered as 4 lanes will be separated by a high-level median along the corridor separating into 2 x 2lanes

3.0 Conclusions

Detailed Traffic Survey has been undertaken for the project stretch from Minerva Junction to Hudson Circle. Following are the Conclusions based on various outcome from data analysis.

- Morning Peak and Evening Peak Hour Traffic at all **8 Junctions** have resulted in more than 10,000 PCU per hour. Therefore, as per the guidelines stipulated under Section 4.5 of IRC-92-2017, all these junction locations **Warrant for Grade Separators**.
- All these junctions along JC Road from Minerva Junction to Hudson Circle are closely located, hence providing individual grade separator for each junction does not yield greater relief for the at grade traffic. Therefore, it is proposed to provide **Elevated Corridor** from **Minerva Junction to Hudson Circle**.

- As per the analysis, it is observed that major composition of traffic are 2-Wheelers followed by Four Wheelers and then Autos. The composition of Buses and goods vehicles are less in percentage.
- As per the sample O-D analysis at Minerva Junction, Influence factors accounts to 40% for the Zones located beyond Hudson Circle indicating the through traffic. Hence, the same percentage has been considered in estimating through traffic from RV Road and Sajjana Rao Circle road.
- Similarly, the O-D analysis at Minerva Junction, Influence factors accounts to 45% for the Zones located beyond Minerva Junction indicating the through traffic. Hence, the same percentage has been considered in estimating through traffic from Nrupathunga Road and Raja Ram Mohan Roy Road entering Krumbigal (Lalbagh) Road.
- The present data analysis, indicates that around **2753 PCU per Hour** will use the proposed **Elevated Road from Minerva Junction to Hudson Circle direction** and **1527 PCU per Hour** will use the **Elevated Road in Hudson Circle to Minerva Junction direction**.
- Based on the above estimated traffic, the minimum lane requirement in each direction for the current traffic is ***3-Lanes in Minerva Junction to Hudson Circle Direction*** and ***2-Lanes in Hudson Circle to Minerva Junction Direction. However, considering the site constraints w.r.t available right of way, 4 lane elevated road is proposed. From traffic analysis, for traffic from Minerva circle to Hudson circle direction during the peak hour the LOS will be crossing LOS-C by 10%***
- Overall, due to the proposed Elevated Road, there will be **relief to at grade traffic** on JC Road in the range of **25% to 50% at different section of Road**.

Based on the details analysis of data and its outcome, it is recommended to propose a 4-lnae divided Elevated Road between Minerva Junction and Hudson Circle to facilitate two-way traffic movement to provide relief to At-Grade Road.

APPENDIX - 2 – GEOTECH REPORT

REPORT ON THE GEOTECHNICAL INVESTIGATION FOR THE PROPOSED ELEVATED ROAD FROM MINERVA CIRCLE TO HUDSON CIRCLE, BANGALORE

1.0 INTRODUCTION

M/s. Bruhath Bangalore Mahanagara Palike, Bangalore has entrusted M/s. Vax Consultants Pvt Ltd, Chennai as DPR consultants. M/s. VCPL entrusted us to carry out the geotechnical investigation for the proposed Elevated Road from Hudson Circle to Minerva Circle, Bangalore. The primary objective of this investigation was to establish the ground condition at the site and evaluating the bearing pressure and other engineering design parameters through the field and laboratory tests. This report consists of the details about the field and laboratory tests performed and the recommendations made based on the results of the tests.

2.0 SCOPE

The scope of work includes both the field tests and laboratory tests. Twelve boreholes by mechanical drilling method are planned at the location to obtain the sub-surface stratification. Fig.1 (Client's reference drawing) shows the location of the boreholes on the entire plan of the proposed construction site.

3.0 FIELD INVESTIGATION

Rotary drilling method

The field investigation consists of advancing 150mm dia boreholes using rotary drilling with bentonite mud circulation. Standard penetration test (SPT) was conducted at every 1.50m Interval as per IS: 2131 – 1981. The number of blows for 30cm penetration of split spoon sampler was recorded as N-values. 100mm dia undisturbed samples (UDS) were collected at intermediate depths using thin walled tube samplers as per IS 2132. The process of drilling, conducting SPT and collecting UDS were continued up to refusal stratum (N>50), Beyond this depth drilling was progressed using NX size TC/diamond bits. The boreholes were terminated when adequate depth of drilling was completed in consultation with the Engineer-in-charge.

The various sub-surface strata are presented in the respective bore charts.

4.0 LABORATORY TESTS

Laboratory Test was performed to evaluate both the index and engineering properties of the soil samples collected during boring. The different tests performed are test for Grain size distribution, Atterberg limits and direct shear tests. The results of these tests are presented in Table 1 to 13.

5.0 SUB SOIL PROFILE

AROUND BH 1

The subsoil consists of from top nil to 3.0m filled up soil followed by greyish medium to fine sandy Clay up to 4.5m depth extends to greyish yellowish yellow clayey medium to fine Sand up to 5.5m. Further to this greyish yellow hard rock is encountered up to termination depth. The borehole is terminated at 9.5m from the existing ground surface. During the time of investigation water table was not encountered up to termination depth.

AROUND BH 2

The subsoil consists of from top nil to 0.5m brownish medium to fine Sand followed by Greyish white hard rock is encountered up to termination depth. The borehole is terminated at 3.5m from the existing ground surface. During the time of investigation water table was not encountered up to termination depth.

AROUND BH 3

The subsoil consists of from top nil to 3.0m greyish brown sandy Silt with the presence of Clay binders followed by greyish to yellowish medium to fine sandy Silty Clay up to 8.8m depth. Further to this greyish white hard rock s encountered up to termination depth. The borehole is terminated at 11.8m from the existing ground surface. During the time of investigation water table was encountered at 7.5m depth below the existing ground surface.

AROUND BH 4

The subsoil consists of from top nil to 0.5m brownish medium to fine Sand followed by Greyish white hard rock is encountered up to termination depth. The borehole is terminated at 3.5m from the existing ground surface. During the time of investigation water table was not encountered up to termination depth.

AROUND BH 5

The subsoil consists of from top nil to 3.0m brownish medium to fine sandy Silt with the presence of clay binders followed by greyish to brownish yellow medium to fine sandy Silty Clay up to 6.0m depth below to this brownish to greyish weathered rock is encountered up to termination. Further to this greyish hard rock is encountered up to termination depth. The borehole is terminated at 8.5m from the existing ground surface. During the time of investigation water table was encountered at 5.0m below the existing ground surface.

AROUND BH 6

The subsoil consists of from top nil to 3.5m filled up soil followed by grayish medium to fine sandy Clay up to 6.0m depth below to this greyish to brownish clayey fine to medium Sand is encountered up to termination depth. During the time of investigation water table was not encountered up to termination depth. The borehole is terminated at 10.5m from the existing ground surface.

AROUND BH 7

The subsoil consists of from top nil to 3.5m reddish brown silty medium to fine Sand followed by whitish to yellowish grey medium to fine sandy Silt is observed up to 4.5m depth below to this greyish to yellowish medium to fine sandy Silt with the presence of mica up to 7.2m depth. Further to this whitish grey hard rock is encountered up to termination depth. The borehole is terminated at 10.2m from the existing ground surface. During the time of investigation water table was encountered below 6.5m depth from the existing ground surface.

AROUND BH 8

The subsoil consists of from top nil to 1.5m filled up soil followed by reddish medium to fine sandy Silt up to 4.5m depth below to this reddish to whitish yellow medium to fine sandy Silt with the presence of mica is encountered up to 7.5m depth. Further to this brownish to yellowish grey medium to fine sandy Silt with the presence of mica up to 17.0m depth extends to whitish grey to brownish silty medium to fine Sand with the presence of mica up to termination depth. During the time of investigation water table was not encountered up to termination depth. The borehole is terminated at 27.0m from the existing ground surface.

AROUND BH 9

The subsoil consists of from top nil to 1.5m filled up soil followed by greyish red to brownish medium to fine sandy Silt up to 6.0m depth below to this brownish to greyish medium to fine sandy Silt is encountered up to termination depth. During the time of investigation water table was not encountered up to termination depth. The borehole is terminated at 17.0m from the existing ground surface.

AROUND BH 10

The subsoil consists of from top nil to 1.5m filled up soil followed by reddish medium to fine sandy Silt with the presence of mica up to 7.5m depth below to this yellowish medium to fine sandy Silt with the presence of mica 10.5m depth. Further to this brownish to yellowish medium to fine sandy Silt with the presence of mica is observed up to termination depth. The borehole is terminated at 19.0m from the existing ground surface. During the time of investigation water table was encountered below 11.5m depth from the existing ground surface.

AROUND A1

The subsoil consists of from top nil to 0.5m filled up soil followed by brownish to yellowish sandy Silt with the presence of clay binders 6.0m depth extends to greenish weathered rock is observed up to 12.0m depth below to this yellowish to greyish hard rock is encountered up to termination depth. The borehole is terminated at 15m from the existing ground surface. During the time of investigation water table was not encountered up to termination depth.

AROUND A2

The subsoil consists of from top nil to 0.5m filled up soil followed by yellowish to greyish sandy Silt with 3.0m depth extends to greenish brown clayey Sand is encountered up to 6.0m depth followed by yellowish grey weathered rock is observed up to 12.0m depth below to this yellowish to greyish hard rock is encountered up to termination depth. The borehole is terminated at 15m from the existing ground surface. During the time of investigation water table was not encountered up to termination depth.

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

The following conclusions and recommendations are given based on field and laboratory investigations.

1. The soil strata up to1.5m/3.0 are found to be filled up in nature.
2. The soil strata below 1.5m/3.0m are found to be medium stiff / medium dense in nature.
3. The silt/clay presence in the soil is found to be medium compressible in nature.
4. The clay presence in the soil is found to be medium plastic in nature.
5. During the time of investigation water table was not encountered up to termination depth.

6.2 RECOMMENDATIONS

The following recommendations are made based on the detailed investigation conducted and the conclusions drawn.

1. The foundation for all structure shall be taken to a minimum depth of 1.50m below the proposed road level.
2. Individual footing/combined foundation may be designed with the following allowable bearing pressure of, which gives a factor of safety of 2.5 against shear failure and for allowable settlement of 25mm.

Depth, m	Size of Footing	SBC kN/sq.m											
		BH 1	BH 2	BH 3	BH 4	BH 5	BH 6	BH 7	BH 8	BH 9	BH 10	A1	A2
1.5	2m X 2m	--	--	94	--	91	105	100	137	122	122	100	100
	3m X 3m	--	--	101	--	98	114	108	147	132	132	108	108
	5m X 5m	--	--	120	--	114	135	128	171	113	157	128	128
3.0	3m X 3m	145	--	120	--	120	227	252	263	173	263	252	252
	5m X 5m	158	--	95	--	187	242	238	238	113	238	238	238

Note: *When ever hard rock is observed at shallow depth foundation for all structure with minimum grip length and SBC of* ***800kN/m^2*** *is recommended at founding level.*

Note: *All the structures shall be found on the natural ground only. The above said SBC are indicative and represents virgin soil strata only.*

For the design of Individual/combined foundation by considering the allowable settlement of 40mm following SBC is recommended at different depths.

Depth, m	Width of Footing	SBC kN/sq.m											
		BH 1	BH 2	BH 3	BH 4	BH 5	BH 6	BH 7	BH 8	BH 9	BH 10	A1	A2
1.5	2m	--	--	300	--	400	--	356	--	278	356	356	356
	3m	--	--	450	--	294	--	326	--	226	326	326	326
	5m	--	--	450	--	258	--	300	--	181	300	300	300
3.0	3m	233	--	193	--	420	--	422	422	278	422	422	422
	5m	254	--	152	--	300	--	381	381	181	381	381	381

Note: The above said SBC by neglecting over burden pressure.

4. Provide 100mm down size well graded aggregates well compacted to 8" depth followed by 4" sand cushion wherever **silty /clayey** stratum is observed at founding level.
5. The bottom of foundation shall be properly leveled and verified for loose pockets/weaker zones and if found, the same shall be replaced with lean concrete.

Alternatively,

1. Bored cast-in-situ pile foundation is recommended based on load consideration. Piles shall be socketed into hard rock for at least 1.0 times the diameter of pile or 5 times the diameter in hard strata or weathered rock.
2. In cases of pile founded in a hard stratum the spacing will be governed by the competency of end bearing strata. The minimum spacing in such cases, shall be 2.5times the diameter of the shaft. In case pile resting on hard rock 2 times the diameter may be adopted.
3. Piles deriving their bearing capacity mainly from the friction shall be sufficiently apart to ensure that the zones of soils from which piles derive their support do not overlap to such an extent that their bearing values are reduced. Generally spacing in such cases shall not be less than three times the diameter of the shaft.
4. For the design consideration (Design length of pile= 20.0m from existing ground) following allowable load carrying capacity of the piles may be considered.

However actual load carrying capacity of pile may be arrived by conducting initial pile load test.

Diameter, mm	**Allowable Load, tones**
750	**228**
900	**420**
1000	**550**

for GEOENGINEERING COMPANY PRIVATE LTD

(JAYAPRAKASH. K. N)

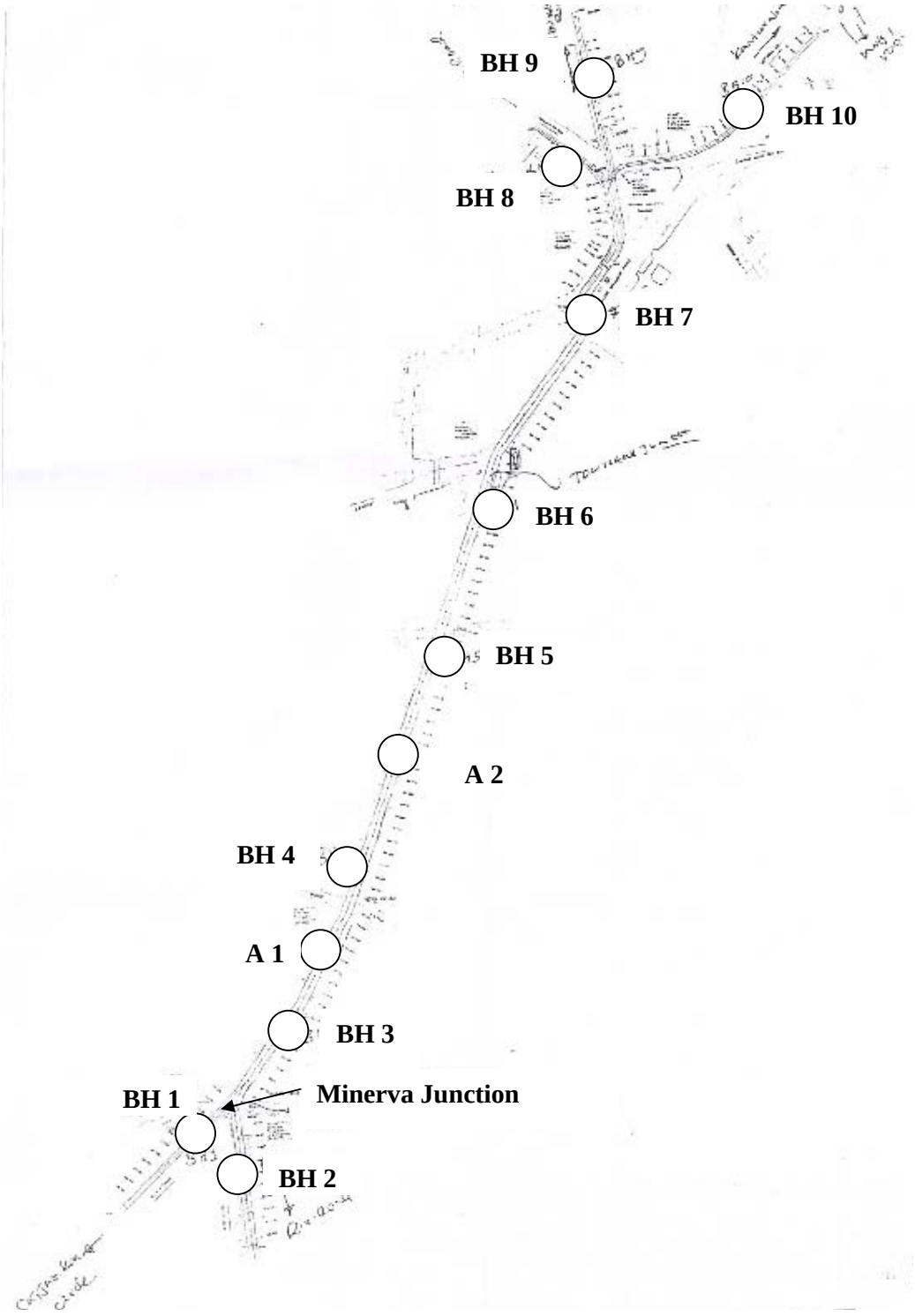


Fig 1: Location of Boreholes

BORE HOLE NUMBER: 1

Site: Hudson to Minerva — Location: V.V.Puram Road

Type of Boring: Rotary Drilling — Borehole diameter: 100 mm

GWT: Not Encountered

DESCRIPTION	Legend	Depth (m)	Sample	N – Value	SPT Test Results No. of blows N/30 cms
					10 20 30 40 50
		0.0	--	--	
Filled Up Soil		1.5	SPT DS	17	
Greyish medium to fine sandy Clay		3.0	SPT DS	17	
Greyish yellow clayey medium to fine Sand		4.5	SPT DS	>50	
		5.5	SPT DS	>100	
Greyish yellow hard rock		7.0	CR	--	
		9.5	CR	--	

Run, m	C.R, %	R.Q.D,%
5.5 to 7.0	76	36
7.0 to 9.5	80	75

SPT – Standard Penetration Test — UDS – Undisturbed soil sample

DS – Disturbed soil Sample — GWT – Ground Water Table

CR- Core Recovery — RQD- Rock Quality Designation

Fig. 2: Bore log at BH: 1

BORE HOLE NUMBER: 2

Site: Hudson to Minerva — Location: on RV Road

Type of Boring: Rotary Drilling — Borehole diameter: 100 mm

GWT: Not Encountered

DESCRIPTION	Legend	Depth (m)	Sample	N – Value	SPT Test Results No. of blows N/30 cms				
					10	20	30	40	50
Brownish silty medium to fine Sand		0.0	--	--					
		0.5	DS	--					
					Run, m	C.R, %	R.Q.D,%		
					0.5 to 2.0	64.67	53.33		
					2.0 to 3.5	86	86		
Greyish white hard rock		2.0	CR	--					
		3.5	CR	--					

SPT – Standard Penetration Test — UDS – Undisturbed soil sample

DS – Disturbed soil Sample — GWT – Ground Water Table

CR- Core Recovery — RQD- Rock Quality Designation

Fig. 3: Bore log at BH: 2

BORE HOLE NUMBER: 3

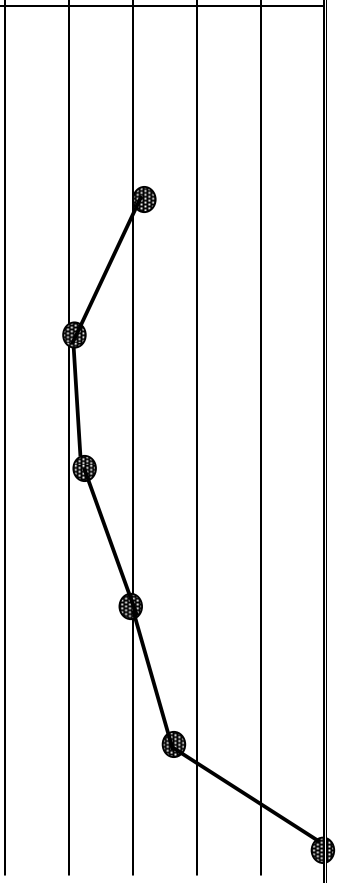
Site: Hudson to Minerva — Location: J.C.Road-Near Parking

Type of Boring: Rotary Drilling — Borehole diameter: 100 mm

GWT: 7.5m

DESCRIPTION	Legend	Depth (m)	Sample	N – Value
		0.0	--	--
		0.5	DS	--
Greyish brown medium to fine sandy Clay		1.5	SPT DS	22
		3.0	SPT DS	11
Greyish to greyish yellow medium to fine sandy Clay		4.5	SPT DS	12
		6.0	SPT DS	20
		7.5	SPT DS	27
		8.8	SPT DS	>100
Greyish white hard rock		10.3	CR	
		11.8	CR	--

SPT Test Results
No. of blows N/30 cms



Run, m	C.R, %	R.Q.D,%
8.8 to 10.3	55	35
10.3 to 11.8	69	60

SPT – Standard Penetration Test — UDS – Undisturbed soil sample

DS – Disturbed soil Sample — GWT – Ground Water Table

CR- Core Recovery — RQD- Rock Quality Designation

Fig. 4: Bore log at BH: 3

BORE HOLE NUMBER: 4

Site: Hudson to Minerva

Type of Boring: Rotary Drilling Borehole diameter: 100 mm

GWT: Not Encoutered Location: on JC Road Near Petro Bunk

DESCRIPTION	Legend	Depth (m)	Sample	N – Value	SPT Test Results No. of blows N/30 cms				
					10	20	30	40	50
Brownish silty medium to fine Sand		0.0	--	--					
		0.5	DS	--					
Greyish white hard rock		2.0	CR	--					
		3.5	CR	--					

Run, m	C.R, %	R.Q.D,%
0.5 to 2.0	81	81
2.0 to 3.5	88	88

SPT – Standard Penetration Test UDS – Undisturbed soil sample

DS – Disturbed soil Sample GWT – Ground Water Table

CR- Core Recovery RQD- Rock Quality Designation

Fig. 5: Bore log at BH: 4

BORE HOLE NUMBER: 5

Site: Hudson to Minerva

Type of Boring: Rotary Drilling Borehole diameter: 100 mm

GWT: 5.0m Location: J.C.Road- Ravindra Kala Kshetra

DESCRIPTION	Legend	Depth (m)	Sample	N – Value	SPT Test Results No. of blows N/30 cms
					10 20 30 40 50
		0.0	--	--	
		0.5	DS	--	
Brownish medium to fine sandy Clay		1.5	DS	--	
		3.0	SPT DS	18	
Greyish brown to yellowish grey medium to fine sandy Clay		4.5	SPT DS	22	
		6.0	SPT DS	>50	
Brownish to greyish brown weathered rock		6.5	SPT DS	>100	
		7.0	CR		
Greyish hard rock		8.5	CR		

Run, m	C.R, %	R.Q.D,%
6.5 to 7.0	30.13	30.13
7.0 to 8.5	72	70

SPT – Standard Penetration Test UDS – Undisturbed soil sample

DS – Disturbed soil Sample GWT – Ground Water Table

CR- Core Recovery RQD- Rock Quality Designation

Fig. 6: Bore log at BH: 5

BORE HOLE NUMBER: 6

Site: Hudson to Minerva — Location: at Town Hall Jctn

Type of Boring: Rotary Drilling — Borehole diameter: 100 mm

GWT: Not Encountered

DESCRIPTION	Legend	Depth (m)	Sample	N – Value	SPT Test Results No. of blows N/30 cms
					10 20 30 40 50
Filled up soil		0.0	--	--	
		3.5	SPT DS	07	
Greyish brown to yellowish grey medium to fine sandy Clay		4.5	SPT DS	23	
		6.0	SPT DS	>50	
Brownish to greyish clayey fine to medium Sand		7.0	SPT DS	>100	
		7.5	--		
Whitish grey hard rock		9.0	CR	--	
		10.5	CR	--	

Run, m	C.R, %	R.Q.D,%
7.5 to 9.0	35	22
9.0 to 10.5	67	55

SPT – Standard Penetration Test — UDS – Undisturbed soil sample

DS – Disturbed soil Sample — GWT – Ground Water Table

CR- Core Recovery — RQD- Rock Quality Designation

Fig. 7: Bore log at BH: 6

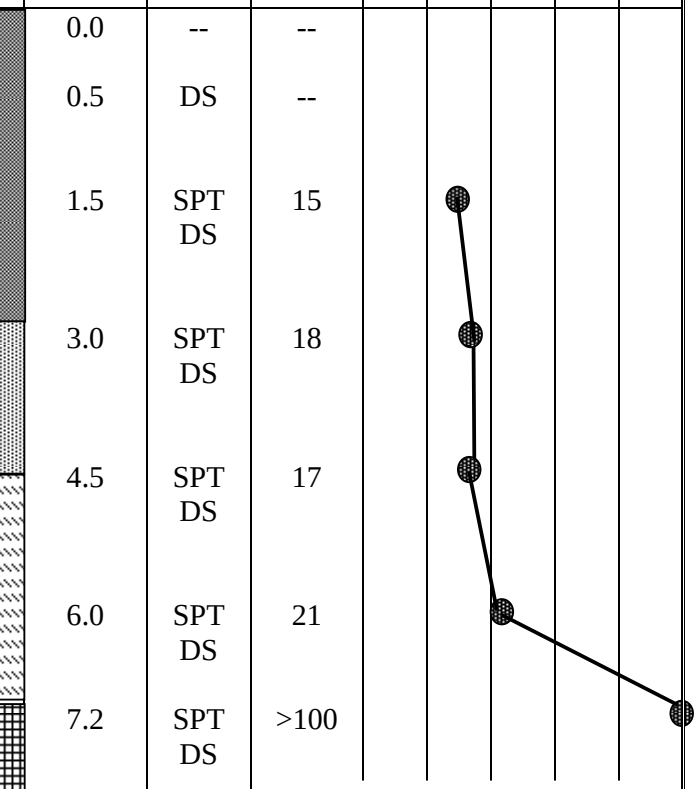
BORE HOLE NUMBER: 7

Site: Hudson to Minerva — Location: Badam house Jtn.

Type of Boring: Rotary Drilling — Borehole diameter: 100 mm

GWT: 6.5m

DESCRIPTION	Legend	Depth (m)	Sample	N – Value
		0.0	--	--
		0.5	DS	--
Reddish brown silty medium to fine Sand		1.5	SPT DS	15
		3.0	SPT DS	18
Whitish to yellowish grey medium to fine sandy Silt		4.5	SPT DS	17
Greyish yellow medium to fine sandy Silt with the presence of mica		6.0	SPT DS	21
		7.2	SPT DS	>100
		7.75	CR	
Whitish grey hard rock		8.7	CR	
		10.2	CR	



Run, m	C.R, %	R.Q.D,%
7.2 to 7.75	93.64	93.64
7.75 to 8.7	98	87
8.7 to 10.2	98	90

SPT – Standard Penetration Test — UDS – Undisturbed soil sample

DS – Disturbed soil Sample — GWT – Ground Water Table

CR- Core Recovery — RQD- Rock Quality Designation

Fig. 8: Bore log at BH: 7

BORE HOLE NUMBER: 8

Site: Hudson to Minerva — Location: Ulsoor Gate junction.

Type of Boring: Rotary Drilling — Borehole diameter: 100 mm

GWT: Not Encountered

DESCRIPTION	Legend	Depth (m)	Sample	N – Value	SPT Test Results No. of blows N/30 cms
					10 20 30 40 50
Filled up soil		0.0	--	--	
		1.5	DS	--	
Reddish brown medium to fine sandy Silt		3.0	SPT DS	18	
		4.5	SPT DS	12	
Reddish to whitish yellow medium to fine sandy Silt with the presence of mica		6.0	SPT DS	20	
		7.5	SPT DS	27	
Brownish to yellowish grey medium to fine sandy Silt with the presence of mica		9.0	SPT DS	37	
		10.5	SPT DS	47	

SPT – Standard Penetration Test — UDS – Undisturbed soil sample

DS – Disturbed soil Sample — GWT – Ground Water Table

CR- Core Recovery — RQD- Rock Quality Designation

Fig. 9: Bore log at BH: 8 (Contd…)

BORE HOLE NUMBER: 8 (Contd…)

Site: Hudson to Minerva — Location: Ulsoor Gate junction.

Type of Boring: Rotary Drilling — Borehole diameter: 100 mm

GWT: Not Encountered

DESCRIPTION	Legend	Depth (m)	Sample	N – Value	SPT Test Results No. of blows N/30 cms
					10 20 30 40 50
Brownish to yellowish grey medium to fine sandy Silt with the presence of mica		10.5	SPT DS	47	
		12.0	DS	--	
		14.0	SPT DS	34	
		17.0	SPT DS	>50	
Whitish grey to brownish silty fine to medium Sand with the presence of mica		20.0	SPT DS	>100	
		24.0	SPT DS	>100	
Yellowish to whitish grey hard rock		25.5	CR		
		27.0	CR		

Run, m	C.R, %	R.Q.D,%
24.0 to 25.5	35	30
25.5 to 27.0	66	66

SPT – Standard Penetration Test — UDS – Undisturbed soil sample

DS – Disturbed soil Sample — GWT – Ground Water Table

CR- Core Recovery — RQD- Rock Quality Designation

Fig. 10: Bore log at BH: 8

BORE HOLE NUMBER: 9

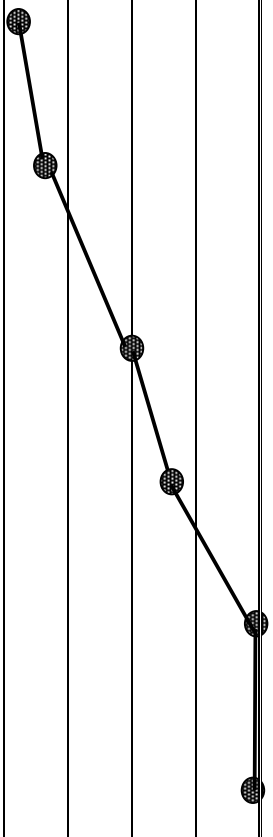
Site: Hudson to Minerva — Location: Nrupatunga Road

Type of Boring: Rotary Drilling — Borehole diameter: 100 mm

GWT: Not Encountered

DESCRIPTION	Legend	Depth (m)	Sample	N – Value
Filled up soil		0.0	--	--
		1.5	DS	--
Greyish red to brownish medium to fine sandy Silt		3.0	SPT DS	13
		4.5	SPT DS	17
Brownish to greyish medium to fine sandy Silt with the presence of mica		6.0	SPT DS	30
		7.5	SPT DS	37
		9.0	SPT DS	>50
		10.5	SPT DS	>50

SPT Test Results No. of blows N/30 cms



SPT – Standard Penetration Test — UDS – Undisturbed soil sample

DS – Disturbed soil Sample — GWT – Ground Water Table

CR- Core Recovery — RQD- Rock Quality Designation

Fig. 11: Bore log at BH: 9

BORE HOLE NUMBER: 9 (Contd…)

Site: Hudson to Minerva — Location: Nrupatunga Road

Type of Boring: Rotary Drilling — Borehole diameter: 100 mm

GWT: Not Encountered

DESCRIPTION	Legend	Depth (m)	Sample	N – Value	SPT Test Results No. of blows N/30 cms
					10 20 30 40 50
Brownish to greyish medium weathered rock with the presence of mica		10.5	SPT DS	>50	
		12.0	SPT DS	>100	
		13.5	SPT DS	>100	
		14.0	SPT DS	>100	
Whitish grey hard rock		15.5	CR		
		17.0	CR		

Run, m	C.R, %	R.Q.D,%
14.0 to 15.5	58	44
15.5 to 17.0	69	50

SPT – Standard Penetration Test — UDS – Undisturbed soil sample

DS – Disturbed soil Sample — GWT – Ground Water Table

CR- Core Recovery — RQD- Rock Quality Designation

Fig. 12: Bore log at BH: 9

BORE HOLE NUMBER: 10

Site: Hudson to Minerva — Location: Kasturbha Road

Type of Boring: Rotary Drilling — Borehole diameter: 100 mm

GWT: 11.5m

DESCRIPTION	Legend	Depth (m)	Sample	N – Value	SPT Test Results No. of blows N/30 cms
					10 20 30 40 50
Filled up soil		0.0	--	--	
		1.5	DS	--	
Reddish medium to fine sandy Silt with the presence of mica		3.0	SPT DS	16	
		4.5	SPT DS	18	
		6.0	SPT DS	19	
		7.5	SPT DS	24	
Yellowish fine to medium sandy Silt with the presence of mica		9.0	SPT DS	26	
		10.5	SPT DS	29	

SPT – Standard Penetration Test — UDS – Undisturbed soil sample

DS – Disturbed soil Sample — GWT – Ground Water Table

CR- Core Recovery — RQD- Rock Quality Designation

Fig. 13: Bore log at BH: 10 (Contd…)

BORE HOLE NUMBER: 10 (Contd…)

Site: Hudson to Minerva — Location: Kasturbha Road

Type of Boring: Rotary Drilling — Borehole diameter: 100 mm

GWT: 11.5m

DESCRIPTION	Legend	Depth (m)	Sample	N – Value	SPT Test Results No. of blows N/30 cms (10 / 20 / 30 / 40 / 50)
Brownish to yellowish fine to medium sandy Silt with the presence of mica		10.5	SPT DS	29	
		13.0	SPT DS	40	
		16.0	SPT DS	>50	
Greyish to yellowish hard rock		17.5	CR		
		19.0	CR	--	

Run, m	C.R, %	R.Q.D,%
16.0 to 17.5	42	35
17.5 to 19.0	66	50

SPT – Standard Penetration Test — UDS – Undisturbed soil sample

DS – Disturbed soil Sample — GWT – Ground Water Table

CR- Core Recovery — RQD- Rock Quality Designation

Fig. 14: Bore log at BH: 10

BORE HOLE NUMBER: A1

Site: Hudson to Minerva — Location: Near Bharat Talkies

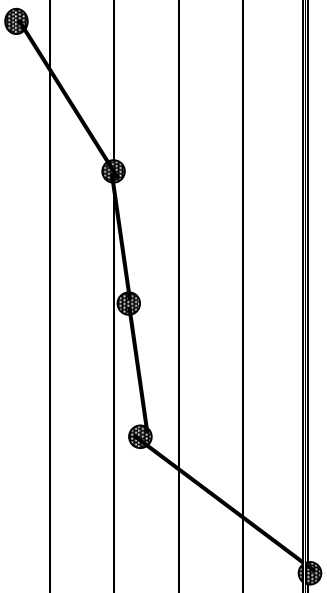
Type of Boring: Rotary Drilling — Borehole diameter: 150 mm

GWT: Nil

DESCRIPTION	Legend	Depth (m)	Sample	N - Value
Filled up Soil		0.0	--	--
Brownish fine sandy Silt with clay binders		0.5	DS	--
		1.5	SPT UDS	06
Brownish to yellowish grey sandy Silt with clay binders		3.0	SPT DS	20
		4.5	SPT DS	21
		6.0	SPT DS	23
Greenish weathered rock		7.5	DS	>50
		9.0	DS	--
		10.5	DS	--
		12.0	DS	--

SPT Test Results No. of blows N/30 cms

10 20 30 40 50



SPT – Standard Penetration Test — UDS – Undisturbed soil sample

DS – Disturbed soil Sample — GWT – Ground Water Table

Fig. 15: Bore log at BH: A 1 (Contd…)

BORE HOLE NUMBER: A1 (Contd…)

Site: Hudson to Minerva — Location: Near Bharat Talkies

Type of Boring: Rotary Drilling — Borehole diameter: 150 mm

GWT: Nil

DESCRIPTION	Legend	Depth (m)	Sample	N - Value	SPT Test Results No. of blows N/30 cms				
					10	20	30	40	50
		12.0	DS	--					
Yellowish to greyish white hard rock		13.5	CR						
		15.0	CR	--					

Run, m	C.R, %	R.Q.D,%
12.0 to 13.5	38	30
13.5 to 15.0	66	49

SPT – Standard Penetration Test — UDS – Undisturbed soil sample

DS – Disturbed soil Sample — GWT – Ground Water Table

CR – Core Recovery — RQD – Rock Quality Designation

Fig. 16: Bore log at BH: A1

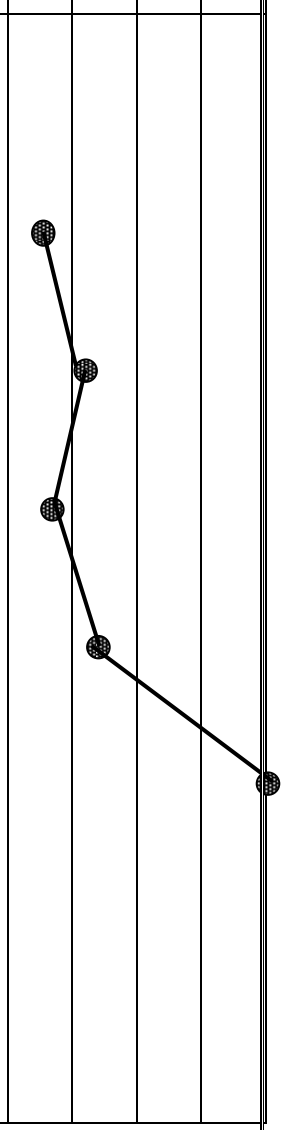
BORE HOLE NUMBER: A2

Site: Hudson to Minerva — Location: Near Shivaji Talkies

Type of Boring: Rotary Drilling — Borehole diameter: 150 mm

GWT: Nil

DESCRIPTION	Legend	Depth (m)	Sample	N - Value
		0.0	--	--
Filled up Soil		0.5	DS	--
Yellowish grey fine sandy Silt		1.5	SPT UDS	17
		3.0	SPT DS	21
Greyish brown clayey medium to fine Sand		4.5	SPT DS	18
		6.0	SPT C.R	23
		7.5	DS	>50
Yellowish white weathered rock		9.0	DS	--
		10.5	DS	--
		12.0	DS	--



SPT – Standard Penetration Test — UDS – Undisturbed soil sample

DS – Disturbed soil Sample — GWT – Ground Water Table

CR – Core Recovery — RQD – Rock Quality Designation

Fig. 17: Bore log at BH: A2

BORE HOLE NUMBER: A2

Site: Hudson to Minerva — Location: Near Shivaji Talkies

Type of Boring: Rotary Drilling — Borehole diameter: 150 mm

GWT: Nil

DESCRIPTION	Legend	Depth (m)	Sample	N - Value	SPT Test Results No. of blows N/30 cms				
					10	20	30	40	50
		12.0	DS	--					
Yellowish white hard rock		13.5	CR						
		15.0	CR	--					

Run, m	C.R, %	R.Q.D,%
12.0 to 13.5	40	30
13.5 to 15.0	65	45

SPT – Standard Penetration Test — UDS – Undisturbed soil sample

DS – Disturbed soil Sample — GWT – Ground Water Table

CR – Core Recovery — RQD – Rock Quality Designation

Fig. 18: Bore log at BH: A2

Table No. 1 (BH 1)

Depth (m)			1.5	3.0	4.5
Dry density (kN/m^3)			--	--	--
Water Content (%)			13.0	18.5	15.5
Atterberg Limits	**Liquid Limit (%)**		34.9	47.8	32.9
	Plastic Limit (%)		16.4	20.8	15.5
	Plasticity Index (PI)		18.5	27.0	17.3
Grain size Distribution	**Gravel (%)**		0.3	0.0	0.5
	Sand (%)	**Coarse**	1.1	0.0	0.6
		Medium	15.7	10.0	15.9
		Fine	29.6	33.6	34.9
	Silt & Clay		53.4	56.4	48.1
Shear test		**C, (kN/m^2)**	--	25	--
		ϕ, (deg)	--	06	--
IS Classification			CI		

Table No. 2 (BH 3)

Depth (m)			1.5	3.0	4.5	6.0	7.5
Dry density (kN/m^3)			--	--	--	--	--
Water Content (%)			18.7	20.1	15.0	29.9	14.7
Specific Gravity			2.55	2.52	--	--	--
Atterberg Limits	**Liquid Limit (%)**		30.0	41.5	43.5	40.5	--
	Plastic Limit (%)		14.2	16.6	17.0	18.1	--
	Plasticity Index (PI)		15.8	24.9	26.5	22.3	--
Grain size Distribution	**Gravel (%)**		15.2	0.0	0.0	0.0	0.0
	Sand (%)	**Coarse**	3.6	0.9	0.0	1.1	1.8
		Medium	14.7	12.9	16.1	17.2	17.2
		Fine	20.6	28.7	33.3	21.8	23.3
	Silt & Clay		46.0	57.5	50.6	59.9	57.7
Shear test		**C, (kN/m^2)**	26	28	--	--	--
		ϕ, (deg)	04	08	--	--	--
IS Classification			SC	CI			--

Table No. 3 (BH 5)

Depth (m)			3.0	4.5	6.0
Dry density (kN/m^3)			--	--	--
Water Content (%)			18.7	16.4	14.4
Specific Gravity			2.55	2.50	--
Atterberg Limits	**Liquid Limit (%)**		35.8	35.7	--
	Plastic Limit (%)		17.0	16.3	--
	Plasticity Index (PI)		18.7	19.4	--
Grain size Distribution	**Gravel (%)**		1.3	6.7	9.8
	Sand (%)	**Coarse**	1.7	1.6	5.1
		Medium	14.9	9.1	24.9
		Fine	19.5	16.3	17.8
	Silt & Clay		62.7	66.3	42.4
Shear test		**C, (kN/m^2)**	26	29	--
		ϕ, (deg)	08	06	--
IS Classification			CI		--

Table No. 4 (BH 6)

Depth (m)			3.5	4.5	6.0
Dry density (kN/m^3)			--	--	--
Water Content (%)			18.7	12.4	11.4
Atterberg Limits	**Liquid Limit (%)**		37.7	38.4	--
	Plastic Limit (%)		18.4	18.0	--
	Plasticity Index (PI)		19.3	20.4	--
Grain size Distribution	**Gravel (%)**		6.9	0.6	0.0
	Sand (%)	**Coarse**	1.5	0.0	0.4
		Medium	16.0	4.0	23.9
		Fine	28.5	31.5	38.0
	Silt & Clay		47.0	63.9	37.7
Shear test		**C, (kN/m^2)**	30	--	--
		ϕ, (deg)	05	--	--
IS Classification			SC	CI	--

Table No. 5 (BH 7)

Depth (m)			3.0	4.5	6.0
Dry density (kN/m^3)			--	--	--
Water Content (%)			21.9	23.2	20.7
Specific Gravity			42.0	44.5	44.3
Atterberg Limits	**Liquid Limit (%)**		37.7	38.4	--
	Plastic Limit (%)		18.4	18.0	--
	Plasticity Index (PI)		19.3	20.4	--
Grain size Distribution	**Gravel (%)**		0.3	0.3	0.8
	Sand (%)	**Coarse**	2.8	6.4	9.1
		Medium	20.8	32.6	31.5
		Fine	15.1	14.7	13.4
	Silt & Clay		61.0	46.0	45.3
Shear test	**C, (kN/m^2)**		30	--	--
	ϕ, (deg)		06	--	--
IS Classification			CI	SC	--

Table No. 6 (BH 8)

Depth (m)			3.0	4.5	6.0	7.5	9.0
Dry density (kN/m^3)			--	--	--	--	--
Water Content (%)			35.7	22.2	23.8	23.9	25.3
Specific Gravity			2.47	--	--	--	--
Atterberg Limits	**Liquid Limit (%)**		49.1	--	27.0	38.6	38.1
	Plastic Limit (%)		--	--	--	--	--
	Plasticity Index (PI)		Non Plastic	--	Non Plastic	Non Plastic	Non Plastic
Grain size Distribution	**Gravel (%)**		0.0	0.4	1.0	0.0	0.0
	Sand (%)	**Coarse**	5.1	2.0	0.1	0.0	2.4
		Medium	26.4	19.1	21.6	23.5	24.0
		Fine	15.4	15.8	13.9	25.0	19.6
	Silt & Clay		53.0	62.7	63.3	51.5	54.0
Shear test	**C, (kN/m^2)**		28	--	--	--	--
	ϕ, (deg)		07	--	--	--	--
IS Classification			ML	--	ML		

Table No. 7 (BH 8 Contd…)

Depth (m)			10.5	14.0	23.7	18.1
Dry density (kN/m^3)			--	--	--	--
Water Content (%)			26.7	22.3	23.3	18.1
Specific Gravity			--	--	--	--
Atterberg Limits	**Liquid Limit (%)**		38.2	--	--	--
	Plastic Limit (%)		--	--		--
	Plasticity Index (PI)		Non Plastic	--	--	--
Grain size Distribution	**Gravel (%)**		0.0	0.0	0.0	0.3
	Sand (%)	**Coarse**	0.7	0.3	0.4	5.9
		Medium	27.2	26.9	32.9	37.6
		Fine	25.5	22.4	22.6	18.0
	Silt & Clay		46.7	50.3	44.1	38.2
Shear test		**C, (kN/m^2)**	--	--	--	--
		ϕ, (deg)	--	--	--	--
IS Classification			SC	--	--	--

Table No. 8 (BH 9)

Depth (m)			3.0	4.5	6.0	7.5	9.0
Dry density (kN/m^3)			--	--	--	--	--
Water Content (%)			17.9	16.7	19.1	18.7	18.9
Specific Gravity			--	--			
Atterberg Limits	**Liquid Limit (%)**		42.6	42.2	--	--	--
	Plastic Limit (%)		18.0	20.1	--	--	--
	Plasticity Index (PI)		24.6	22.2	--	--	--
Grain size Distribution	**Gravel (%)**		0.5	0.0	0.2	0.1	1.2
	Sand (%)	**Coarse**	3.3	4.6	0.4	10.4	6.5
		Medium	21.1	246	29.0	33.9	39.5
		Fine	21.0	19.4	14.8	16.6	24.4
	Silt & Clay		54.2	51.4	49.6	38.9	28.4
Shear test		**C, (kN/m^2)**	27	--	--	--	--
		ϕ, (deg)	08	--	--	--	--
IS Classification			CI		--	--	--

Table No. 9 (BH 10)

Depth (m)			3.0	4.5	6.0	7.5	9.0
Dry density (kN/m^3)			--	--	--	--	--
Water Content (%)			14.3	22.2	18.6	23.2	24.2
Atterberg Limits	Liquid Limit (%)		36.0	36.7	37.5	35.8	36.3
	Plastic Limit (%)		18.1	--	--	--	--
	Plasticity Index (PI)		17.8	--	Non Plastic	Non Plastic	Non Plastic
Grain size Distribution	Gravel (%)		0.3	0.0	0.0	0.0	0.0
	Sand (%)	Coarse	2.3	0.2	0.1	0.0	1.2
		Medium	13.4	13.2	22.1	26.1	31.7
		Fine	14.6	25.4	21.0	21.1	22.9
	Silt & Clay		69.4	61.3	56.8	52.8	44.3
Shear test	C, (kN/m^2)		29	--	--	--	--
	ϕ, (deg)		07	--	--	--	--
IS Classification			CI	--	ML		SC

Table No. 10 (BH 10 Contd…)

Depth (m)			10.5	13.5	16.0
Dry density (kN/m^3)			--	--	--
Water Content (%)			22.3	23.3	18.1
Specific Gravity			--	--	--
Atterberg Limits	Liquid Limit (%)		38.2	--	--
	Plastic Limit (%)		--	--	
	Plasticity Index (PI)		Non Plastic	--	--
Grain size Distribution	Gravel (%)		0.0	0.0	1.5
	Sand (%)	Coarse	0.8	0.0	2.9
		Medium	34.8	28.1	35.1
		Fine	18.7	24.4	18.0
	Silt & Clay		45.7	47.5	42.5
Shear test	C, (kN/m^2)		--	--	--
	ϕ, (deg)		--	--	--
IS Classification			SC	--	--

Table No: 11 (BH A1)

Depth (m)		1.5	3.0	4.5	6.0
Dry density (g/cc)		1.62	--	--	--
Water Content (%)		16.2	27.0	23.5	13.5
Liquid Limit (%)		28.7	28.3	--	--
Plastic Limit (%)		22.0	15.9	--	--
Grain size Distribution Gravel (%)		1.4	0.3	0.2	0.9
Sand (%)	Coarse	1.5	0.2	0.3	0.8
	Medium	10.4	17.0	12.9	31.2
	Fine	15.4	34.1	30.6	28.2
Silt & Clay		71.3	48.5	56.0	38.9
Shear test	C,(kg/cm^2)	0.11	--	--	--
	ϕ, (deg)	29	--	--	--

TABLE NO: 12 (BH A2)

Depth (m)		1.5	3.0	4.5	6.0
Dry density (g/cc)		1.68	--	--	--
Water Content (%)		16.2	10.9	16.6	11.0
Liquid Limit (%)		--	20.0	--	23.8
Plastic Limit (%)		--	Non Plastic	--	17.1
Grain size Distribution Gravel (%)		0.0	0.0	0.0	0.0
Sand (%)	Coarse	0.2	0.0	0.3	0.5
	Medium	14.0	12.4	15.5	24.3
	Fine	32.7	57.3	12.8	35.1
Silt & Clay		63.2	30.4	71.4	40.1
Shear test	C,(kg/cm^2)	0.12	--	--	--
	ϕ, (deg)	28	--	--	--

TABLE No: 13 Laboratory Test on Rock Samples

Borehole No	Depth (m)	Uniaxial Unconfined compression strength, kg/cm^2
1	5.5 to 7.0	275
2	0.5 to 2.0	525
3	8.8 to 10.0	590
5	6.5 to 7.0	1385
7	7.2 to 7.5	1345

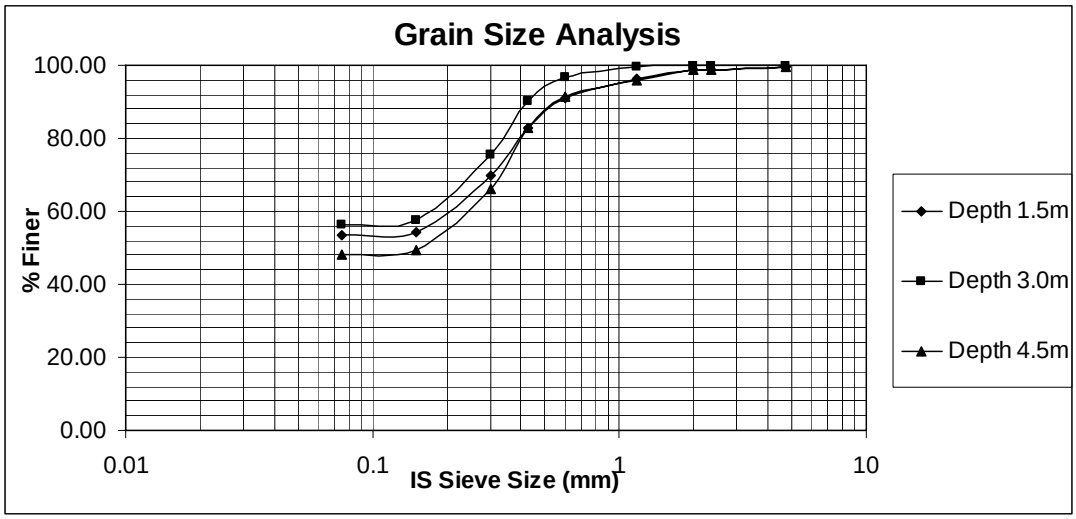


Fig No. 19: Grain Size Curves at BH 1

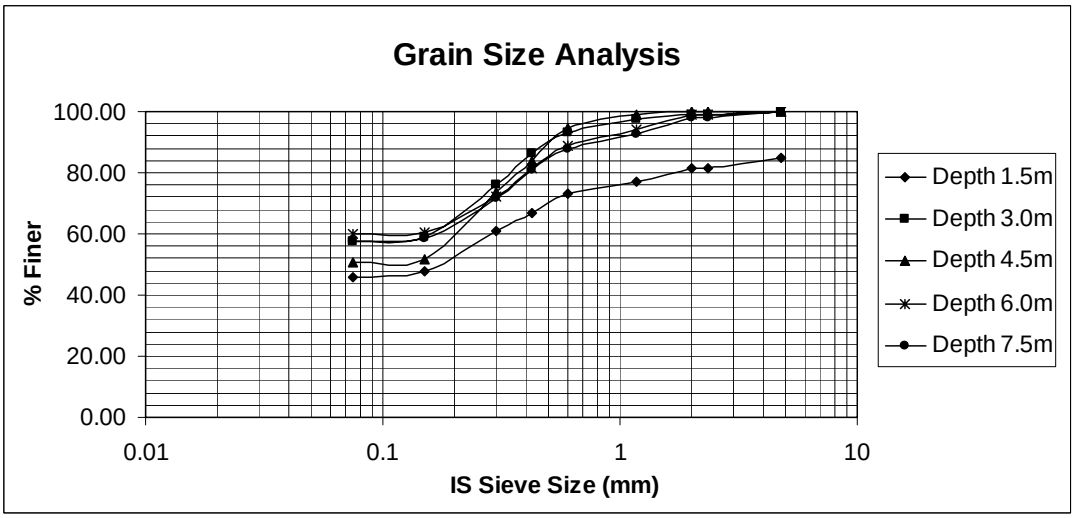


Fig No. 20: Grain Size Curves at BH 3

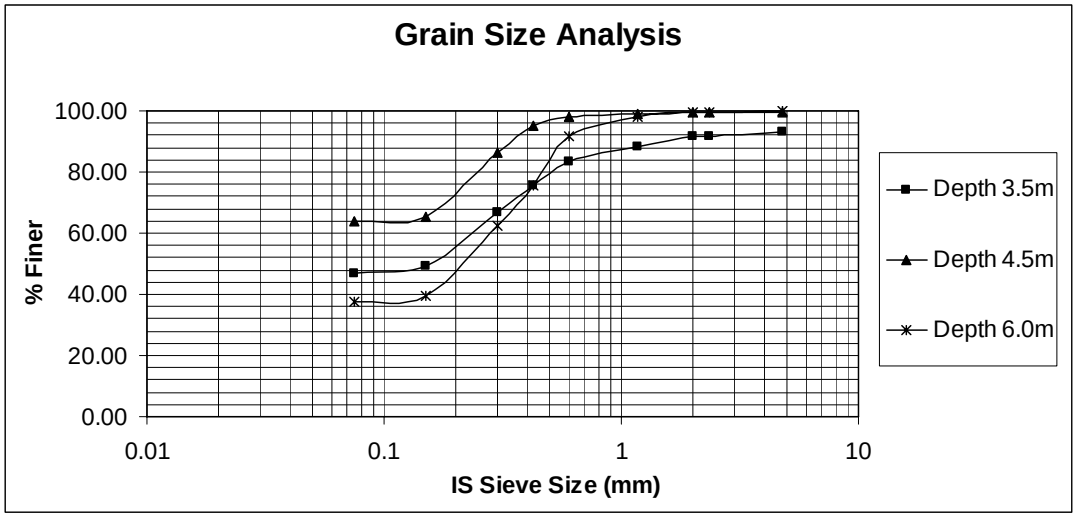


Fig No. 21: Grain Size Curves at BH 4

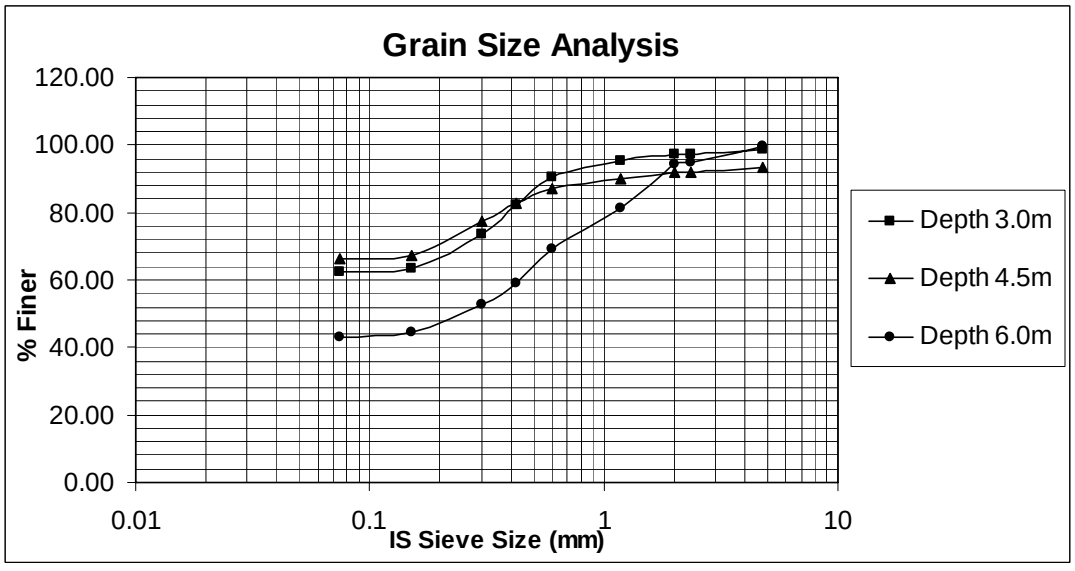


Fig No. 22: Grain Size Curves at BH 5

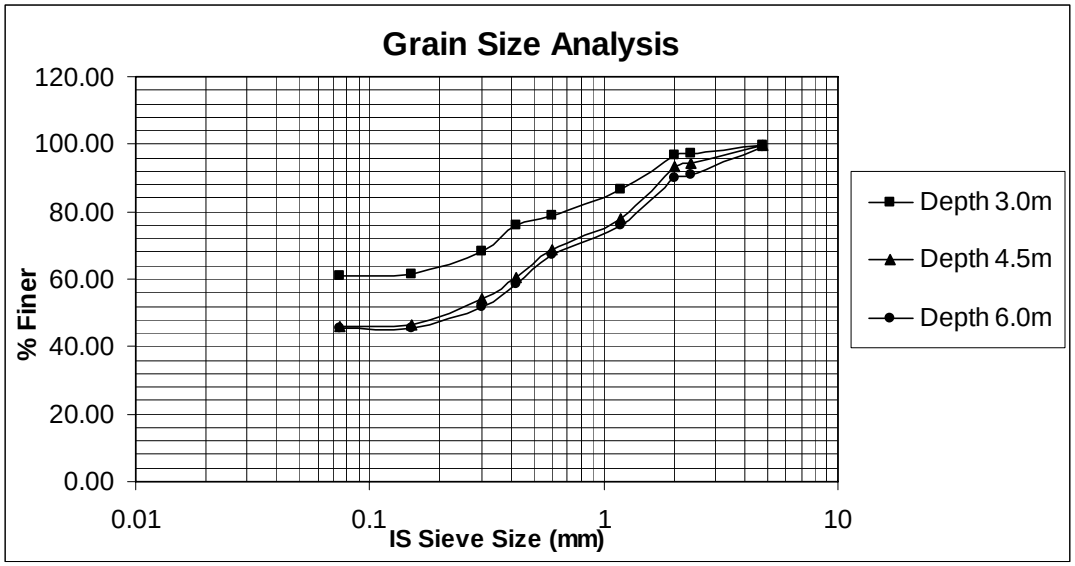


Fig No. 23 Grain Size Curves at BH 7

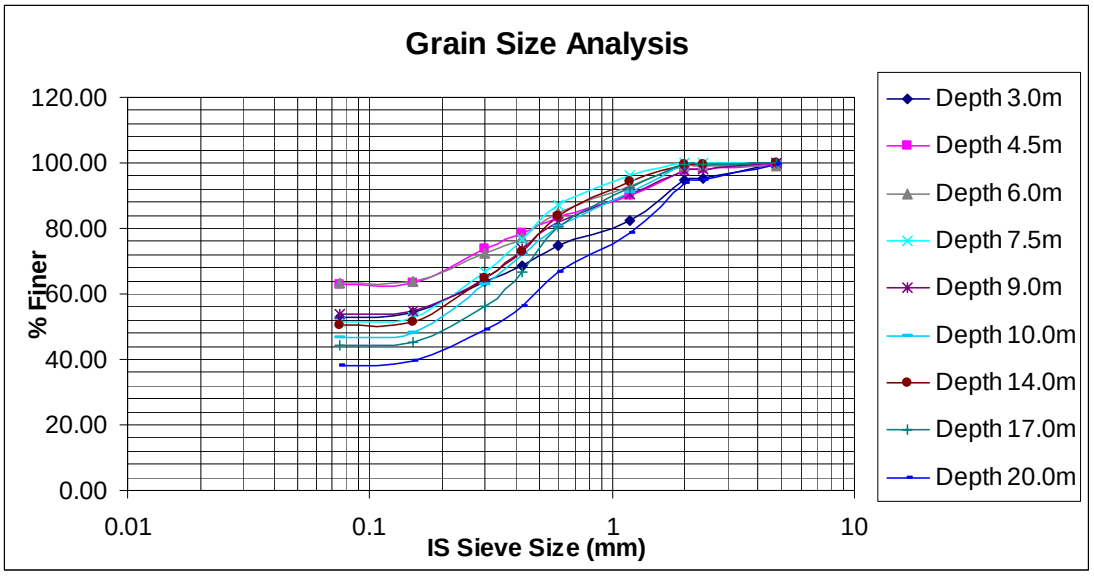


Fig No. 24: Grain Size Curves at BH 8

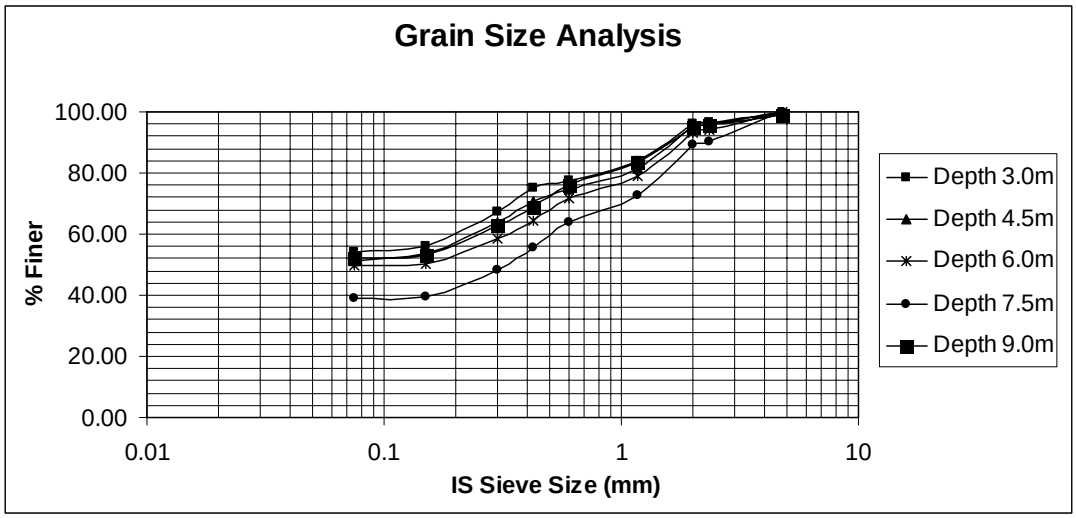


Fig No. 25: Grain Size Curves at BH 9

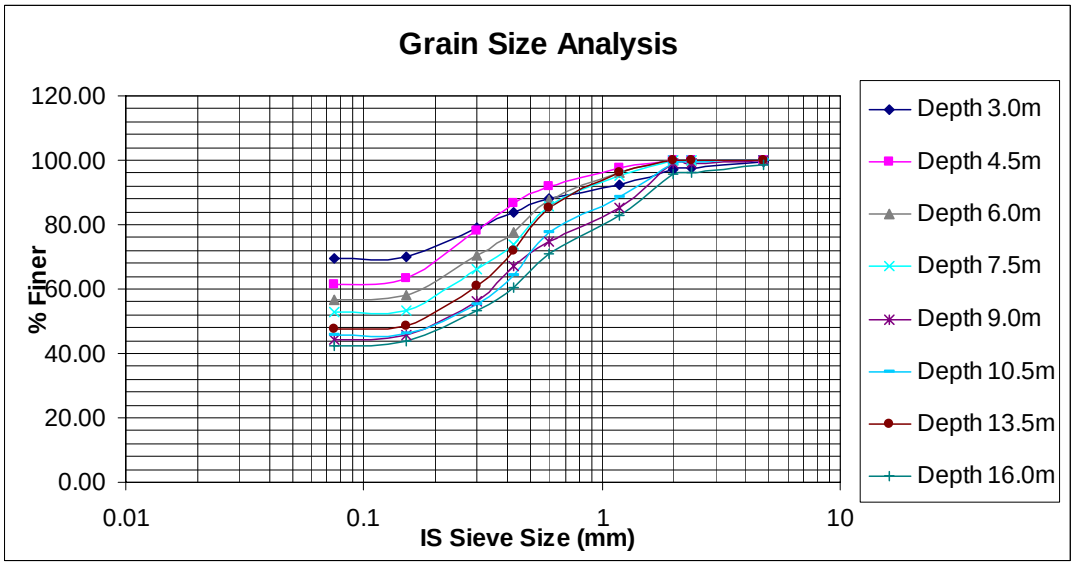


Fig No. 26: Grain Size Curves at BH 10

Specimen Calculation -IS:6403-1981 for BH 7

Depth of footing, D=	**1.5**	m	ø=	**27**	Y=	**19**	kN/m3		
			ø'=	**18.8**	y'=	**9.19**	kN/m3	dc=	(1+0.2(D/B)*sqrt*Nø
Width of footing, B=	**2**	**m**			Nø=	tan2*(45+ø/2)			**1.24**
Length of footing, L=	**2**	**m**			sqrtNø=	**1.63**		dq,dy=	(1+0.1(D/B)*sqrt*Nø
Ref. Bore hole No.=	**BH 7**								**1.12**

Local Shear Failure, **Qult =cN'c.sc.dc.ic+Yd(N'q-1)sq.dq.iq+0.5BYNy.sy.dy.iy.W'**

Qult=	c	Nc	sc	dc	ic	Y	D	Nq	sq	dq	iq	B	Y	Ny	sy	dy	iy	W'
	0	17.19	1	1.24	1	19	1.5	5.9	1.2	1.12	1	2	19	4.84	0.6	1.12	1	1

Square footing, qd	**250.0**	kN/m2
Qs with F.S (2.5)	**100.0**	kN/m2

Design of a Pile Foundation - Single Pile BH 8

Piles in Cohesionless Soils

Diameter of Pile, D =	1000	mm	=	1	m
Length of Pile, L =	20	m			
S.Density of soil at pile tip, r =	1	g/cc	=	10	kN/m^3
Angle of internal friction at pile tip =	40	degrees			

Nr = 107.4 (from IS 6403 for the given phi value)

Nq = 125 (from IS 2911 for the given phi value)

Ap = 0.7850 m^2

Ultimate Bearing Capacity, Qu = Qus + Qup

Qup = Ap (1/2 * D * r * Nr + P_D * Nq) = 13177.80 kN

Qus =Sum (K * P_{Di} tan(delta) * Asi) = 740.49 kN

Qu = 13918.28 kN

Factor of Safety = 2.5

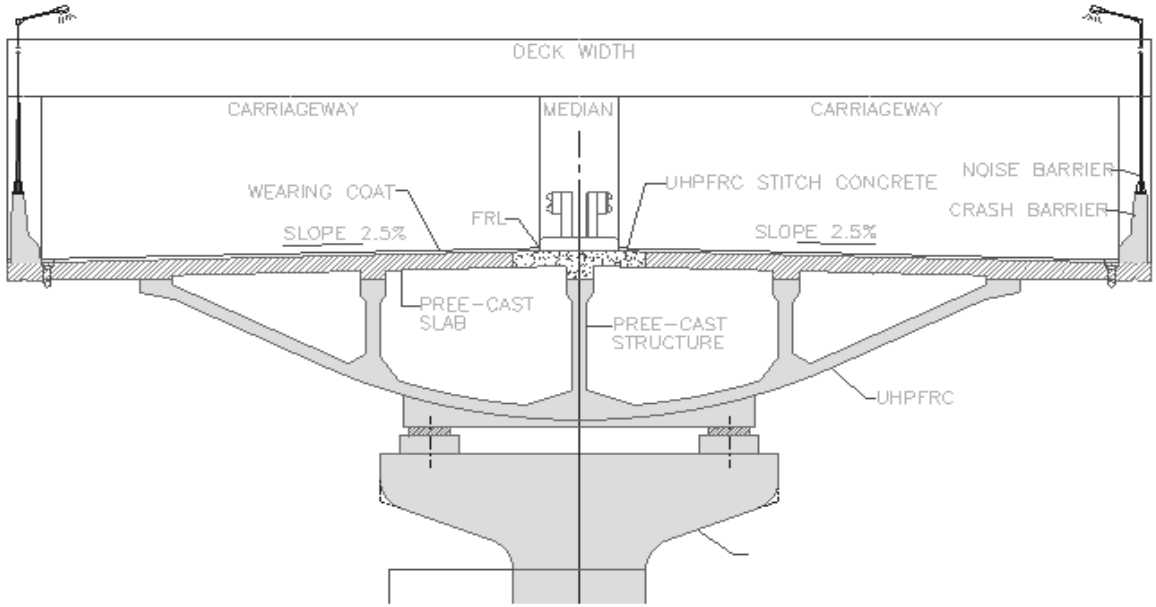
Qua = 5567.3 kN

556.73 Tonne

APPENDIX - 3 – PRELIMINARY DESIGN REPORT

Preliminary Design of Fish Belly Superstructure – 50m Span and 17.2m deck width

Design of Fish Belly Superstructure ***For 50m Span***



3. Data for Design

Proposed Section

Span of Bridge (C/C of bearings)		=	48400	mm		
C/C of piers		=	50000	mm		
Carriageway Width		=	15200	mm		
O/O of Parapet		=	17200	mm		
CantileverProjection		=	1982	mm		
Width of Bottom Slab		=	5300	mm	4500 mm is the c/c of bearing	
Angle of inclination for the Webs.		=	26.000	^{0}	0.45 ^{c}	
Thickness of Deck Slab		=	250	mm		
Thickness of Slab at cant. Tip		=	300	mm		
Thickness of Slab at cant. Face		=	300	mm		
Overall Depth of the Girder	Maximum Depth	=	2712	mm		
Thickness of Soffit Slab (Running X^n)		=	200	mm		
Thickness of Soffit Slab (End X^n)		=	200	mm		
Web thickness (Running X^n)		=	200	mm	456.23 eff.	
Web thickness (End X^n)		=	200	mm	456.23 eff.	
Diaphragm present at end or not		=	y	(Y/N)		
If yes, Thickness of diaphragm		=	1000	mm		
Over hang of girder beyond bearings		L1 =	400	mm	0 mm will be grouted later	
Overhang beyond end diaphragm			810	mm		
Crash Barrier			500	X	1000 X 4 side/s	
Crash Barrier Load			8.0	kN/m		
Median Load			11.0	kN/m		
Working Point =			150	mm		
Density of Concrete		=	25	KN/m^3		
Intensity of wearing coat load considered =			2	KN/m^2		
Grade of Concrete Used For Box Girder		= M	150			
Characteristic Compressive Strength		=	150	N/mm^2		
Permissible stress in Concrete.		=	85	N/mm^2	CL 3.1.6 NF P18 - 710	
Modulus of Elasticity of Concrete "Ecm" of girder		=	47270	N/mm^2		
Modulus of Elasticity of Concrete "Ecm" of Top Slab		=	35000	N/mm^2		
Modular Ratio		=	0.7404			
HTS steel used in design :	Uncoated stress relieved low relaxation steel conforming to IS:14268					
Modulus of Elasticity of Steel "Es"		=	195000	MPa.		
Area of strand		=	140	mm^2		
Type of cable	= 19	T	15	with duct diameter		

Section Properties *(Composite section properties considering difference in Youngs Modulus of Top Slab and U trough)*													
Distance (x)		0.000	0.500	1.200	3.200	5.700	8.200	10.700	13.700	16.700	19.700	22.700	24.200
Section Properties													
Area		9.6E+06	9.6E+06	9.6E+06	9.6E+06	9.6E+06	9.6E+06	7.9E+06	7.9E+06	7.9E+06	7.9E+06	7.9E+06	7.9E+06
Section CG(y)		1662.0	1662.0	1662.0	1662.0	1662.0	1662.0	1798.0	1798.0	1798.0	1798.0	1798.0	1798.0
I section		7.51	7.51	7.51	7.51	7.51	7.51	6.03	6.03	6.03	6.03	6.03	6.03
Zt		7.15	7.15	7.15	7.15	7.15	7.15	7.15	7.15	7.15	7.15	7.15	7.15
Zb		4.52	4.52	4.52	4.52	4.52	4.52	4.52	4.52	4.52	4.52	4.52	4.52
Section Area		9.56	9.56	9.56	9.56	9.56	9.56	7.94	7.94	7.94	7.94	7.94	7.94
Actual Cross sectional area =		10.49	10.49	10.49	10.49	10.49	10.49	9.13	9.13	9.13	9.13	9.13	9.13

5) Summary of Forces & bending stress calculation

i) Dead Load Stress Resultants from Midas Civil (Includes SW of U trough, Top Slab)

	Section No.	1--1	2--2	3--3	4--4	5--5	6--6	7--7	8--8	9--9	10--10	11--11	12--12	
	Section at	Support	1st Junction	2nd Junction	3rd Junction	4th Junction	5th Junction	6th Junction	7th Junction	8th Junction	9th Junction	10th Junction	L/2	
	Node Numbers	8	9	10	11	12	13	14	15	16	17	18	19	
	Distance (x)	0.000	0.500	1.200	3.200	5.700	8.200	10.700	13.700	16.700	19.700	22.700	24.2	
P(x)	Shear (kN)	5853.20	5722.08	5538.50	5014.00	4358.38	3697.17	3089.41	2403.91	1718.41	1032.91	347.41	4.66	
	BM (kNm)	288.25	2605.57	6546.78	17099.28	28814.76	38891.17	47363.79	55603.75	61787.22	65914.19	67984.65	68248.70	
	Zt	7.15	7.15	7.15	7.15	7.15	7.15	7.15	7.15	7.15	7.15	7.15	7.15	
	Zb	4.52	4.52	4.52	4.52	4.52	4.52	4.52	4.52	4.52	4.52	4.52	4.52	
Bending Stresses	Top Stress	0.03	0.27	0.68	1.77	2.98	4.03	4.90	5.76	6.40	6.83	7.04	7.07	Mpa
	Bottom Stress	-0.06	-0.58	-1.45	-3.79	-6.38	-8.61	-10.48	-12.31	-13.68	-14.59	-15.05	-15.11	Mpa

Stress Resultants from Midas for 4 Lane Loading

	Section No.	1--1	2--2	3--3	4--4	5--5	6--6	7--7	8--8	9--9	10--10	11--11	12--12
	Section at	**Support**	**1st Junction**	**2nd Junction**	**3rd Junction**	**4th Junction**	**5th Junction**	**6th Junction**	**7th Junction**	**8th Junction**	**9th Junction**	**10th Junction**	**L/2**
	Node Numbers	8	9	10	11	12	13	14	15	16	17	18	19
	Distance (x)	0	0.500	1.2	3.2	5.7	8.2	10.7	13.7	16.7	19.7	22.7	24.2
Shear due to Crash Barrier(KN)		546.92	535.62	519.80	474.60	418.10	361.60	305.10	237.30	169.50	101.70	33.90	0.00
Shear due to Wearing Coat(KN)		726.00	711.00	690.00	630.00	555.00	480.00	405.00	315.00	225.00	135.00	45.00	0.00
Shear due to Footpath LL (kNm)		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BM due to Crash Barrier(KN)		6.79	263.85	633.25	1627.65	2743.52	3718.15	4551.52	5365.12	5975.32	6382.12	6585.52	6610.95
BM due to Wearing Coat(KN)		9.01	350.24	840.59	2160.59	3641.84	4935.59	6041.84	7121.84	7931.84	8471.84	8741.84	8775.59
BM due to Footpath LL (kNm)		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bending Stress due to Crash Barrier(kNm)	Top Stress	0.00	0.03	0.07	0.17	0.28	0.39	0.47	0.56	0.62	0.66	0.68	0.68
	Bottom Stress	0.00	-0.06	-0.14	-0.36	-0.61	-0.82	-1.01	-1.19	-1.32	-1.41	-1.46	-1.46

Bending Stress due to Wearing Coat (kNm)	Top Stress	0.00	0.04	0.09	0.22	0.38	0.51	0.63	0.74	0.82	0.88	0.91	0.91
	Bottom Stress	0.00	-0.08	-0.19	-0.48	-0.81	-1.09	-1.34	-1.58	-1.76	-1.88	-1.94	-1.94
Bending Stress due to Footpath LL (kNm)	Top Stress	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Bottom Stress	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total Shear (kN)	1272.92	1246.62	1209.80	1104.60	973.10	841.60	710.10	552.30	394.50	236.70	78.90	0.00
Total Bending Stresses(kNm)	Top Stress	0.00	0.06	0.15	0.39	0.66	0.90	1.10	1.29	1.44	1.54	1.59	1.59
	Bottom Stress	0.00	-0.14	-0.33	-0.84	-1.41	-1.92	-2.34	-2.76	-3.08	-3.29	-3.39	-3.41
	Torsion(KNm)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00

Section No.	13--13	14--14	15--15	16--16	17--17	18--18	19--19	20--20	21--21	22--22	23--23
Section at	**11th Junction**	**12th Junction**	**13th Junction**	**14th Junction**	**15th Junction**	**16th Junction**	**17th Junction**	**18th Junction**	**19th Junction**	**20th Junction**	**Support**
Node Numbers	18	19	20	21	22	23	24	25	26	27	30
Distance (x)	25.700	28.700	31.700	34.700	37.700	40.200	42.700	42.700	47.200	47.900	48.400
Shear due to Crash Barrier(KN)	33.90	101.70	169.50	237.30	305.10	361.60	418.10	474.60	519.80	535.62	546.92
Shear due to Wearing Coat(KN)	45.00	135.00	225.00	315.00	405.00	480.00	555.00	630.00	690.00	711.00	726.00
Shear due to Footpath LL (kNm)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BM due to Crash Barrier(KN)	6585.52	6382.12	5975.32	5365.12	4551.52	3718.15	2743.52	1627.65	633.25	263.85	6.79
BM due to Wearing Coat(KN)	8741.84	8471.84	7931.84	7121.84	6041.84	4935.59	3641.84	2160.59	840.59	350.24	9.01
BM due to Footpath LL (kNm)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bending Stress due to Crash Barrier(kNm) Top Stress	0.68	0.66	0.62	0.56	0.47	0.39	0.28	0.17	0.07	0.03	0.00
Bending Stress due to Crash Barrier(kNm) Bottom Stress	-1.46	-1.41	-1.32	-1.19	-1.01	-0.82	-0.61	-0.36	-0.14	-0.06	0.00
Bending Stress due to Wearing Coat (kNm) Top Stress	0.91	0.88	0.82	0.74	0.63	0.51	0.38	0.22	0.09	0.04	0.00
Bending Stress due to Wearing Coat (kNm) Bottom Stress	-1.94	-1.88	-1.76	-1.58	-1.34	-1.09	-0.81	-0.48	-0.19	-0.08	0.00
Bending Stress due to Footpath LL (kNm) Top Stress	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bending Stress due to Footpath LL (kNm) Bottom Stress	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Shear (kN)	78.90	236.70	394.50	552.30	710.10	841.60	973.10	1104.60	1209.80	1246.62	1272.92
Total Bending Stresses(kNm) Top Stress	1.59	1.54	1.44	1.29	1.10	0.90	0.66	0.39	0.15	0.06	0.00
Total Bending Stresses(kNm) Bottom Stress	-3.39	-3.29	-3.08	-2.76	-2.34	-1.92	-1.41	-0.84	-0.33	-0.14	0.00
Torsion(KNm)	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Maximum Summary of 4 Lanes VLL Forces from Midas Civil

		1--1	2--2	3--3	4--4	5--5	6--6	7--7	8--8	9--9	10--10	11--11	12--12
		Support	1st Junction	2nd Junction	3rd Junction	4th Junction	5th Junction	6th Junction	7th Junction	8th Junction	9th Junction	10th Junction	L/2
	Node Numbers	8	9	10	11	12	13	14	15	16	17	18	19
	Distance (x)	0	0.500	1.2	3.2	5.7	8.2	10.7	13.7	16.7	19.7	22.7	24.2
	Shear (kN)	1659.6	1659.6	1531.8	1510.4	1347.4	1229.5	1133.6	1037.8	935.4	795.6	654.5	654.5
	BM (kNm)	277.3	829.8	1924.3	4791.7	8139.6	10695.1	12914.6	15093.7	16690.2	17725.6	18123.8	18107.2
Bending Stress (MPa)	Top Stress	0.03	0.09	0.20	0.50	0.84	1.11	1.34	1.56	1.73	1.84	1.88	1.87
	Bottom Stress	-0.06	-0.18	-0.43	-1.06	-1.80	-2.37	-2.86	-3.34	-3.69	-3.92	-4.01	-4.01
	Torsion (kNm)	1369.2	1369.2	1263.7	1246.1	1111.6	1014.3	935.2	856.2	771.7	656.4	539.9	539.92

		13--13	14--14	15--15	16--16	17--17	18--18	19--19	20--20	21--21	22--22	23--23
		11th Junction	12th Junction	13th Junction	14th Junction	15th Junction	16th Junction	17th Junction	18th Junction	19th Junction	20th Junction	Support
	Distance (x)	25.7	28.7	31.7	34.7	37.7	40.2	42.7	42.7	47.2	47.9	48.4
	Shear (kN)	654.5	795.6	935.4	1037.8	1133.6	1229.5	1347.4	1510.4	1531.8	1659.6	1659.6
	BM (kNm)	18123.8	17725.6	16690.2	15093.7	12914.6	10695.1	8139.6	4791.7	1924.3	829.8	277.3
Bending Stress (MPa)	Top Stress	1.88	1.84	1.73	1.56	1.34	1.11	0.84	0.50	0.20	0.09	0.03
	Bottom Stress	-4.01	-3.92	-3.69	-3.34	-2.86	-2.37	-1.80	-1.06	-0.43	-0.18	-0.06
	Torsion (kNm)	539.9	656.4	771.7	856.2	935.2	1014.3	1111.6	1246.1	1263.7	1369.2	1369.2

Stresses due to 23 cables Prestressing force after instantneous losses (from Midas)

	1--1	2--2	3--3	4--4	5--5	6--6	7--7	8--8	9--9	10--10	11--11	12--12
	Support	1st Junction	2nd Junction	3rd Junction	4th Junction	5th Junction	6th Junction	7th Junction	8th Junction	9th Junction	10th Junction	L/2
Node Number	8	9	10	11	12	13	14	15	16	17	18	19
Distance (x)	0	0.5	1.2	3.2	5.7	8.2	10.7	13.7	16.7	19.7	22.7	24.2
Axial Force (P)	78801	78896	79023	79407	79864	80400	81380	81860	82268	82273	81868	81641.9
BM (P*e)	47758	49395	51686	58305	66642	74581	87253	87772	88231	88334	87916	87673.0
Top Stress	1.16	1.00	0.77	0.11	-0.71	-1.49	-1.45	-1.46	-1.46	-1.47	-1.47	-1.5
Bottom Stress	18.82	19.19	19.71	21.21	23.11	24.92	29.56	29.74	29.89	29.92	29.77	29.7

	13--13	14--14	15--15	16--16	17--17	18--18	19--19	20--20	21--21	22--22	23--23
	11th Junction	12th Junction	13th Junction	14th Junction	15th Junction	16th Junction	17th Junction	18th Junction	19th Junction	20th Junction	Support
Axial Force (P)	81868	82273	82268	81860	81380	80400	79864	79407	79023	78896	78801
BM (P*e)	87916	88334	88231	87772	87253	74581	66642	58305	51686	49395	47758
Top Stress	-1.47	-1.47	-1.46	-1.46	-1.45	-1.49	-0.71	0.11	0.77	1.00	1.16
Bottom Stress	29.77	29.92	29.89	29.74	29.56	24.92	23.11	21.21	19.71	19.19	18.82

Stresses due to 23 cables Prestressing force after all losses (from Midas)

	1--1	2--2	3--3	4--4	5--5	6--6	7--7	8--8	9--9	10--10	11--11	12--12
	Support	1st Junction	2nd Junction	3rd Junction	Taper Start	Taper end	6th Junction	7th Junction	8th Junction	9th Junction	10th Junction	L/2
Distance (x)	8	9	10	11	12	13	14	15	16	17	18	19
Node Number	0	0.5	1.2	3.2	5.7	8.2	10.7	13.7	16.7	19.7	22.7	24.2
Axial Force (P)	76065	76164	76299	76707	77207	77767	78892	79396	79816	79859	79517.19	79317.1
BM (P*e)	46145	47737	49964	56399	64510	72230	84710	85269	85750	85890	85541.47	85326.3
Top Stress	1.11	0.96	0.74	0.10	-0.70	-1.46	-1.41	-1.43	-1.44	-1.45	-1.44	-1.4
Bottom Stress	18.17	18.54	19.04	20.51	22.36	24.13	28.69	28.87	29.03	29.07	28.95	28.9

	13--13	14--14	15--15	16--16	17--17	18--18	19--19	20--20	21--21	22--22	23--23
	11th Junction	12th Junction	13th Junction	14th Junction	15th Junction	16th Junction	17th Junction	18th Junction	19th Junction	20th Junction	Support
Axial Force (P)	79517	79859	79816	79396	78892	77767	77207	76707	76299	76164	76065
BM (P*e)	85541	85890	85750	85269	84710	72230	64510	56399	49964	47737	46145
Top Stress	-1.44	-1.45	-1.44	-1.43	-1.41	-1.46	-0.70	0.10	0.74	0.96	1.11
Bottom Stress	28.95	29.07	29.03	28.87	28.69	24.13	22.36	20.51	19.04	18.54	18.17

Temperature Gradient Rise (from Midas)

	1--1	2--2	3--3	4--4	5--5	6--6	7--7	8--8	9--9	10--10	11--11	11--11
	Support	1st Junction	2nd Junction	3rd Junction	Taper Start	Taper end	6th Junction	7th Junction	8th Junction	9th Junction	10th Junction	L/2
Node Number	8	9	10	11	12	13	14	15	16	17	18	19
Distance (x)	0	0.6	3.3	6.2	9.1	12.2	15.52	18.84	22.16	25.48	26.48	28.800
Top Stress	-1.18	-1.18	-1.18	-1.18	-1.18	-1.18	-1.18	-1.18	-1.18	-1.18	-1.18	-1.18
Bottom Stress	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20

	13--13	14--14	15--15	16--16	17--17	18--18	19--19	20--20	21--21	22--22	23--23
	11th Junction	12th Junction	13th Junction	14th Junction	15th Junction	16th Junction	17th Junction	18th Junction	19th Junction	20th Junction	Support
Top Stress	-1.18	-1.18	-1.18	-1.18	-1.18	-1.18	-1.18	-1.18	-1.18	-1.18	-1.18
Bottom Stress	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20

Temperature Gradient Fall (from Midas)

	1--1	2--2	3--3	4--4	5--5	6--6	7--7	8--8	9--9	10--10	11--11	11--11
	Support	1st Junction	2nd Junction	3rd Junction	Taper Start	Taper end	6th Junction	7th Junction	8th Junction	9th Junction	10th Junction	L/2
Node Number	8	9	10	11	12	13	14	15	16	17	18	19
Distance (x)	0	0.6	3.3	6.2	9.1	12.2	15.52	18.84	22.16	25.48	26.48	28.800
Top Stress	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
Bottom Stress	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64

	13--13	14--14	15--15	16--16	17--17	18--18	19--19	20--20	21--21	22--22	23--23
	11th Junction	12th Junction	13th Junction	14th Junction	15th Junction	16th Junction	17th Junction	18th Junction	19th Junction	20th Junction	Support
Top Stress	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
Bottom Stress	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64

Rare Combination 4 Lanes :- DL x 1.0 + CB(4L) x 1.0 + WC(4L) x 1.2 + VLL(4L) x 1.0 + Differential Shrinkage x 0.6

	1--1	2--2	3--3	4--4	5--5	6--6	7--7	8--8	9--9	10--10	11--11	11--11
	Support	1st Junction	2nd Junction	3rd Junction	Taper Start	Taper end	6th Junction	7th Junction	8th Junction	9th Junction	10th Junction	L/2
Node Number	8	9	10	11	12	13	14	15	16	17	18	19
Distance (x)	0.000	0.500	1.200	3.200	5.700	8.200	10.700	13.700	16.700	19.700	22.700	24.200
Shear (kN)	8930.96	8770.54	8418.06	7754.98	6789.87	5864.23	5014.13	4057	3093.33	2092.22	1089.76	659.11
BM (kNm)	2443.77	5980.13	11973.68	27971.98	45928.67	61087.71	73940.68	86469.40	95831.59	102048.70	105044.79	105358.17

Factored 4 Lanes :- DL x 1.35 + CB(4L) x 1.35 + WC(4L) x 1.75 + VLL(4L) x 1.5 + Differential Shrinkage x 0.9

	1--1	2--2	3--3	4--4	5--5	6--6	7--7	8--8	9--9	10--10	11--11	11--11
	Support	1st Junction	2nd Junction	3rd Junction	Taper Start	Taper end	6th Junction	7th Junction	8th Junction	9th Junction	10th Junction	L/2
Node Number	8	9	10	11	12	13	14	15	16	17	18	19
Distance (x)	0.000	0.500	1.200	3.200	5.700	8.200	10.700	13.700	16.700	19.700	22.700	24.200
Shear (kN)	12400.122	12181.605	11683.845	10777.68	9440.583	8163.53	6991.7685	5673.5685	4345.5585	2961.3885	1575.1935	987.97
BM (kNm)	3621.0	8522.3	16841.5	39040.9	63977.2	84993.4	102821.6	120202.7	133186.4	141805.0	145944.6	146369.53

7) Check for Stresses

Time Dependent Losses consisting of the following :-

1) DL + PS 23 cables (After Instantaneous Losses)

Load factors as Per Table 3.3 of IRC 6-2016

Dead Load *1* *Minimum Allowable Compression =* *0.5 Mpa (At joints)*

Prestressing *1* *Minimum Allowable Compression =* *0 Mpa (At other locations)*

Maximum Allowable Compression = *85 Mpa CL 3.1.6 NF P18 - 710*

		1--1	2--2	3--3	4--4	5--5	6--6	7--7	8--8	9--9	10--10	11--11	12--12
Distance (x)		0.00	0.50	1.20	3.20	5.70	8.20	10.70	13.70	16.70	19.70	22.70	24.20
Prestress	s t	1.16	1.00	0.77	0.11	-0.71	-1.49	-1.45	-1.46	-1.46	-1.47	-1.47	-1.47
	s b	18.82	19.19	19.71	21.21	23.11	24.92	29.56	29.74	29.89	29.92	29.77	29.69
Dead Load	s t	0.03	0.27	0.68	1.77	2.98	4.03	4.90	5.76	6.40	6.83	7.07	7.07
	s b	-0.06	-0.58	-1.45	-3.79	-6.38	-8.61	-10.48	-12.31	-13.68	-14.59	-15.11	-15.11
Resultant	**s t**	**1.19**	**1.27**	**1.45**	**1.88**	**2.27**	**2.53**	**3.46**	**4.30**	**4.93**	**5.35**	**5.60**	**5.60**
	s b	**18.75**	**18.61**	**18.26**	**17.43**	**16.73**	**16.31**	**19.08**	**17.43**	**16.21**	**15.32**	**14.66**	**14.58**

		13--13	14--14	15--15	16--16	17--17	18--18	19--19	20--20	21--21	22--22	23--23
Distance (x)		25.7	28.7	31.7	34.7	37.7	40.2	42.7	42.7	47.2	47.9	48.4
Prestress	s t	-1.47	-1.47	-1.46	-1.46	-1.45	-1.49	-0.71	0.11	0.77	1.00	1.16
	s b	29.77	29.92	29.89	29.74	29.56	24.92	23.11	21.21	19.71	19.19	18.82
Dead Load	s t	7.07	6.83	6.40	5.76	4.90	4.03	2.98	1.77	0.68	0.27	0.03
	s b	-15.11	-14.59	-13.68	-12.31	-10.48	-8.61	-6.38	-3.79	-1.45	-0.58	-0.06
Resultant	**s t**	**5.60**	**5.35**	**4.93**	**4.30**	**3.46**	**2.53**	**2.27**	**1.88**	**1.45**	**1.27**	**1.19**
	s b	**14.66**	**15.32**	**16.21**	**17.43**	**19.08**	**16.31**	**16.73**	**17.43**	**18.26**	**18.61**	**18.75**

2) DL + PS 23 Cables + Temperature Fall (After Instantaneous Losses)

Load factors as Per Table 3.3 of IRC 6-2016

Dead Load 1 *Minimum Allowable Compression =* *0.5 Mpa (At joints)*

Prestressing 1 *Minimum Allowable Compression =* *0 Mpa (At other locations)*

Temperature Fall 1 *Maximum Allowable Compression =* *85 Mpa CL 3.1.6 NF P18 - 710*

		1--1	2--2	3--3	4--4	5--5	6--6	7--7	8--8	9--9	10--10	11--11	12--12
Distance (x)		0.00	0.50	1.20	3.20	5.70	8.20	10.70	13.70	16.70	19.70	22.70	24.20
Prestress	s t	1.16	1.00	0.77	0.11	-0.71	-1.49	-1.45	-1.46	-1.46	-1.47	-1.47	-1.47
	s b	18.82	19.19	19.71	21.21	23.11	24.92	29.56	29.74	29.89	29.92	29.77	29.69
Dead Load	s t	0.03	0.27	0.68	1.77	2.98	4.03	4.90	5.76	6.40	6.83	7.07	7.07
	s b	-0.06	-0.58	-1.45	-3.79	-6.38	-8.61	-10.48	-12.31	-13.68	-14.59	-15.11	-15.11
Temperature	s t	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
	s b	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64
Resultant	s t	**2.39**	**2.47**	**2.65**	**3.08**	**3.47**	**3.73**	**4.66**	**5.50**	**6.13**	**6.55**	**6.80**	**6.80**
	s b	**20.39**	**20.25**	**19.90**	**19.07**	**18.37**	**17.95**	**20.72**	**19.07**	**17.85**	**16.96**	**16.30**	**16.22**

		13--13	14--14	15--15	16--16	17--17	18--18	19--19	20--20	21--21	22--22	23--23

Distance (x)		*25.7*	*28.7*	*31.7*	*34.7*	*37.7*	*40.2*	*42.7*	*42.7*	*47.2*	*47.9*	*48.4*
Prestress	s t	*-1.47*	*-1.47*	*-1.46*	*-1.46*	*-1.45*	*-1.49*	*-0.71*	*0.11*	*0.77*	*1.00*	*1.16*
	s b	*29.77*	*29.92*	*29.89*	*29.74*	*29.56*	*24.92*	*23.11*	*21.21*	*19.71*	*19.19*	*18.82*
Dead Load	s t	*7.07*	*6.83*	*6.40*	*5.76*	*4.90*	*4.03*	*2.98*	*1.77*	*0.68*	*0.27*	*0.03*
	s b	*-15.11*	*-14.59*	*-13.68*	*-12.31*	*-10.48*	*-8.61*	*-6.38*	*-3.79*	*-1.45*	*-0.58*	*-0.06*
Temperature	s t	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*
	s b	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*
Resultant	s t	***6.80***	***6.55***	***6.13***	***5.50***	***4.66***	***3.73***	***3.47***	***3.08***	***2.65***	***2.47***	***2.39***
	s b	***16.30***	***16.96***	***17.85***	***19.07***	***20.72***	***17.95***	***18.37***	***19.07***	***19.90***	***20.25***	***20.39***

3) DL + PS 23 Cables + Temp Fall + 2 Lane CB (After Instantaneous Losses)

Load factors as Per Table 3.3 of IRC 6-2016

Dead Load	1	*Minimum Allowable Compression =*	*0.5 Mpa (At joints)*
Prestressing	1	*Minimum Allowable Compression =*	*0 Mpa (At other locations)*
Crash Barrier	1	*Maximum Allowable Compression =*	*85 Mpa CL 3.1.6 NF P18 - 710*
Temperature Fall	1		

		1--1	***2--2***	***3--3***	***4--4***	***5--5***	***6--6***	***7--7***	***8--8***	***9--9***	***10--10***	***11--11***	***12--12***
Distance (x)		*0*	*0.5*	*1.20*	*3.2*	*5.7*	*8.2*	*10.7*	*13.7*	*16.7*	*19.7*	*22.70*	*24.2*
Prestress	s t	*1.16*	*1.00*	*0.77*	*0.11*	*-0.71*	*-1.49*	*-1.45*	*-1.46*	*-1.46*	*-1.47*	*-1.47*	*-1.47*
	s b	*18.82*	*19.19*	*19.71*	*21.21*	*23.11*	*24.92*	*29.56*	*29.74*	*29.89*	*29.92*	*29.77*	*29.69*
Dead Load	s t	*0.03*	*0.27*	*0.68*	*1.77*	*2.98*	*4.03*	*4.90*	*5.76*	*6.40*	*6.83*	*7.07*	*7.07*
	s b	*-0.06*	*-0.58*	*-1.45*	*-3.79*	*-6.38*	*-8.61*	*-10.48*	*-12.31*	*-13.68*	*-14.59*	*-15.11*	*-15.11*
Temperature	s t	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*
	s b	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*
Crash Barrier	s t	*0.00*	*0.03*	*0.07*	*0.17*	*0.28*	*0.39*	*0.47*	*0.56*	*0.62*	*0.66*	*0.68*	*0.68*
	s b	*0.00*	*-0.06*	*-0.14*	*-0.36*	*-0.61*	*-0.82*	*-1.01*	*-1.19*	*-1.32*	*-1.41*	*-1.46*	*-1.46*
Resultant	s t	***2.39***	***2.49***	***2.71***	***3.25***	***3.75***	***4.12***	***5.13***	***6.06***	***6.75***	***7.21***	***7.48***	***7.49***
	s b	***20.39***	***20.19***	***19.76***	***18.70***	***17.76***	***17.13***	***19.71***	***17.88***	***16.53***	***15.55***	***14.84***	***14.75***

		13--13	***14--14***	***15--15***	***16--16***	***17--17***	***18--18***	***19--19***	***20--20***	***21--21***	***22--22***	***23--23***
Distance (x)		*25.7*	*28.7*	*31.7*	*34.7*	*37.7*	*40.2*	*42.7*	*42.7*	*47.2*	*47.9*	*48.4*
Prestress	s t	*-1.47*	*-1.47*	*-1.46*	*-1.46*	*-1.45*	*-1.49*	*-0.71*	*0.11*	*0.77*	*1.00*	*1.16*
	s b	*29.77*	*29.92*	*29.89*	*29.74*	*29.56*	*24.92*	*23.11*	*21.21*	*19.71*	*19.19*	*18.82*
Dead Load	s t	*7.07*	*6.83*	*6.40*	*5.76*	*4.90*	*4.03*	*2.98*	*1.77*	*0.68*	*0.27*	*0.03*
	s b	*-15.11*	*-14.59*	*-13.68*	*-12.31*	*-10.48*	*-8.61*	*-6.38*	*-3.79*	*-1.45*	*-0.58*	*-0.06*
Temperature	s t	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*
	s b	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*
Crash Barrier	s t	*0.68*	*0.66*	*0.62*	*0.56*	*0.47*	*0.39*	*0.28*	*0.17*	*0.07*	*0.03*	*0.00*
	s b	*-1.46*	*-1.41*	*-1.32*	*-1.19*	*-1.01*	*-0.82*	*-0.61*	*-0.36*	*-0.14*	*-0.06*	*0.00*
Resultant	s t	***7.48***	***7.21***	***6.75***	***6.06***	***5.13***	***4.12***	***3.75***	***3.25***	***2.71***	***2.49***	***2.39***
	s b	***14.84***	***15.55***	***16.53***	***17.88***	***19.71***	***17.13***	***17.76***	***18.70***	***19.76***	***20.19***	***20.39***

4) DL + PS 23 Cables + Temp Fall + 2 Lane SIDL (After Instantaneous Losses)

Load factors as Per Table 3.3 of IRC 6-2016

Dead Load	1	*Minimum Allowable Compression =*	*0.5 Mpa (At joints)*
Prestressing	1	*Minimum Allowable Compression =*	*0 Mpa (At other locations)*
Crash Barrier	1	*Maximum Allowable Compression =*	*85 Mpa CL 3.1.6 NF P18 - 710*
Wearing Coat	1.2		
Temperature Fall	1		

		1--1	***2--2***	***3--3***	***4--4***	***5--5***	***6--6***	***7--7***	***8--8***	***9--9***	***10--10***	***11--11***	***12--12***
Distance (x)		***0***	***0.5***	***1.2***	***3.2***	***5.7***	***8.2***	***10.7***	***13.7***	***16.7***	***19.7***	***22.7***	***24.2***
Prestress	s t	*1.16*	*1.00*	*0.77*	*0.11*	*-0.71*	*-1.49*	*-1.45*	*-1.46*	*-1.46*	*-1.47*	*-1.47*	*-1.47*
	s b	*18.82*	*19.19*	*19.71*	*21.21*	*23.11*	*24.92*	*29.56*	*29.74*	*29.89*	*29.92*	*29.77*	*29.69*

Dead Load	s *t*	*0.03*	*0.27*	*0.68*	*1.77*	*2.98*	*4.03*	*4.90*	*5.76*	*6.40*	*6.83*	*7.07*	*7.07*
	s *b*	*-0.06*	*-0.58*	*-1.45*	*-3.79*	*-6.38*	*-8.61*	*-10.48*	*-12.31*	*-13.68*	*-14.59*	*-15.11*	*-15.11*
Temperature	s *t*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*
	s *b*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*
Crash Barrier	s *t*	*0.00*	*0.03*	*0.07*	*0.17*	*0.28*	*0.39*	*0.47*	*0.56*	*0.62*	*0.66*	*0.68*	*0.68*
	s *b*	*0.00*	*-0.06*	*-0.14*	*-0.36*	*-0.61*	*-0.82*	*-1.01*	*-1.19*	*-1.32*	*-1.41*	*-1.46*	*-1.46*
Wearing Coat	s *t*	*0.00*	*0.04*	*0.09*	*0.22*	*0.38*	*0.51*	*0.63*	*0.74*	*0.82*	*0.88*	*0.91*	*0.91*
	s *b*	*0.00*	*-0.08*	*-0.19*	*-0.48*	*-0.81*	*-1.09*	*-1.34*	*-1.58*	*-1.76*	*-1.88*	*-1.94*	*-1.94*
Resultant	s *t*	***2.39***	***2.54***	***2.82***	***3.52***	***4.21***	***4.73***	***5.88***	***6.94***	***7.74***	***8.26***	***8.56***	***8.58***
	s *b*	***20.38***	***20.10***	***19.53***	***18.13***	***16.79***	***15.81***	***18.10***	***15.99***	***14.42***	***13.30***	***12.52***	***12.42***

		13--13	***14--14***	***15--15***	***16--16***	***17--17***	***18--18***	***19--19***	***20--20***	***21--21***	***22--22***	***23--23***
Distance (x)		***25.7***	***28.7***	***31.7***	***34.7***	***37.7***	***40.2***	***42.7***	***42.7***	***47.2***	***47.9***	***48.4***
Prestress	*s t*	*-1.47*	*-1.47*	*-1.46*	*-1.46*	*-1.45*	*-1.49*	*-0.71*	*0.11*	*0.77*	*1.00*	*1.16*
	s b	*29.77*	*29.92*	*29.89*	*29.74*	*29.56*	*24.92*	*23.11*	*21.21*	*19.71*	*19.19*	*18.82*
Dead Load	s t	*7.07*	*6.83*	*6.40*	*5.76*	*4.90*	*4.03*	*2.98*	*1.77*	*0.68*	*0.27*	*0.03*
	s b	*-15.11*	*-14.59*	*-13.68*	*-12.31*	*-10.48*	*-8.61*	*-6.38*	*-3.79*	*-1.45*	*-0.58*	*-0.06*
Temperature	s t	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*
	s b	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*

Crash Barrier	s t	*0.68*	*0.66*	*0.62*	*0.56*	*0.47*	*0.39*	*0.28*	*0.17*	*0.07*	*0.03*	*0.00*
	s b	*-1.46*	*-1.41*	*-1.32*	*-1.19*	*-1.01*	*-0.82*	*-0.61*	*-0.36*	*-0.14*	*-0.06*	*0.00*
Wearing Coat	s t	*0.91*	*0.88*	*0.82*	*0.74*	*0.63*	*0.51*	*0.38*	*0.22*	*0.09*	*0.04*	*0.00*
	s b	*-1.94*	*-1.88*	*-1.76*	*-1.58*	*-1.34*	*-1.09*	*-0.81*	*-0.48*	*-0.19*	*-0.08*	*0.00*
Resultant	s t	***8.56***	***8.26***	***7.74***	***6.94***	***5.88***	***4.73***	***4.21***	***3.52***	***2.82***	***2.54***	***2.39***
	s b	***12.52***	***13.30***	***14.42***	***15.99***	***18.10***	***15.81***	***16.79***	***18.13***	***19.53***	***20.10***	***20.38***

5) DL + PS 23 Cables (After All Losses) + 2 Lane SIDL + 2 Lane VLL (Accompanying) + Temperature Fall (Leading)

Load factors as Per Table 3.3 of IRC 6-2016

Loads	*Rare Combination*	*Frequent Combination*	*Quasi Permanent Combination*
Dead Load	1	1	1
Superior Prestressing	1.1	1.1	1.1
Inferior Prestressing	0.9	0.9	0.9
Crash Barrier	1	1	1
Wearing Coat	1.2	1.2	1.2
VLL Leading	0.75	0.75	0
Temperature Fall	1	0.5	0.5
Differential Shrinkage	1	1	1

Minimum Allowable Compression = *0.5 Mpa (At joints)*
Minimum Allowable Compression = *0 Mpa (At other locations)*
Maximum Allowable Compression = *85 Mpa CL 3.1.6 NF P18 - 710*
Maximum Allowable Compression = *54 Mpa (For Frequent and quasi permanent combination)*

		1--1	***2--2***	***3--3***	***4--4***	***5--5***	***6--6***	***7--7***	***8--8***	***9--9***	***10--10***	***11--11***	***12--12***	
Node Numbers		***0***	***0.5***	***1.2***	***3.2***	***5.7***	***8.2***	***10.7***	***13.7***	***16.7***	***19.7***	***22.7***	***24.2***	
Prestress	s *t*	*1.11*	*0.96*	*0.74*	*0.10*	*-0.70*	*-1.46*	*-1.41*	*-1.43*	*-1.44*	*-1.45*	*-1.44*	*-1.44*	
	s *b*	*18.17*	*18.54*	*19.04*	*20.51*	*22.36*	*24.13*	*28.69*	*28.87*	*29.03*	*29.07*	*28.95*	*28.88*	
Dead Load	s *t*	*0.03*	*0.27*	*0.68*	*1.77*	*2.98*	*4.03*	*4.90*	*5.76*	*6.40*	*6.83*	*7.07*	*7.07*	
	s *b*	*-0.06*	*-0.58*	*-1.45*	*-3.79*	*-6.38*	*-8.61*	*-10.48*	*-12.31*	*-13.68*	*-14.59*	*-15.11*	*-15.11*	
Temperature	s *t*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	
	s *b*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	
Crash Barrier	s *t*	*0.00*	*0.03*	*0.07*	*0.17*	*0.28*	*0.39*	*0.47*	*0.56*	*0.62*	*0.66*	*0.68*	*0.68*	
	s *b*	*0.00*	*-0.06*	*-0.14*	*-0.36*	*-0.61*	*-0.82*	*-1.01*	*-1.19*	*-1.32*	*-1.41*	*-1.46*	*-1.46*	
Wearing Coat	s *t*	*0.00*	*0.04*	*0.09*	*0.22*	*0.38*	*0.51*	*0.63*	*0.74*	*0.82*	*0.88*	*0.91*	*0.91*	
	s *b*	*0.00*	*-0.08*	*-0.19*	*-0.48*	*-0.81*	*-1.09*	*-1.34*	*-1.58*	*-1.76*	*-1.88*	*-1.94*	*-1.94*	
VLL	s *t*	*0.03*	*0.09*	*0.20*	*0.50*	*0.84*	*1.11*	*1.34*	*1.56*	*1.73*	*1.84*	*1.88*	*1.87*	
	s *b*	*-0.06*	*-0.18*	*-0.43*	*-1.06*	*-1.80*	*-2.37*	*-2.86*	*-3.34*	*-3.69*	*-3.92*	*-4.01*	*-4.01*	
Tension due to Torsion	s *t*	*0.00*	*-0.37*	*-0.34*	*-0.34*	*-0.30*	*-0.27*	*-0.25*	*-0.23*	*-0.21*	*-0.18*	*-0.15*	*-0.15*	
	s *b*	*0.00*	*-0.37*	*-0.34*	*-0.34*	*-0.30*	*-0.27*	*-0.25*	*-0.23*	*-0.21*	*-0.18*	*-0.15*	*-0.15*	
Differential Shrinkage	s *t*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	
	s *b*	*-0.18*	*-0.18*	*-0.18*	*-0.18*	*-0.18*	*-0.18*	*-0.18*	*-0.18*	*-0.18*	*-0.18*	*-0.18*	*-0.18*	
Resultant (Superior Prestress)	s *t*	***2.56***	***2.37***	***2.75***	***3.64***	***4.57***	***5.27***	***6.61***	***7.86***	***8.80***	***9.43***	***9.80***	***9.80***	***Rare Combination***
	s *b*	***21.33***	***20.61***	***19.93***	***18.16***	***16.44***	***15.20***	***17.51***	***15.09***	***13.30***	***12.05***	***11.25***	***11.16***	
Resultant (Inferior Prestress)	s *t*	***2.34***	***2.18***	***2.60***	***3.62***	***4.71***	***5.56***	***6.89***	***8.14***	***9.08***	***9.72***	***10.08***	***10.09***	
	s *b*	***17.69***	***16.90***	***16.12***	***14.06***	***11.97***	***10.37***	***11.78***	***9.31***	***7.50***	***6.24***	***5.46***	***5.39***	
Resultant (Superior Prestress)	s *t*	***1.96***	***1.77***	***2.15***	***3.04***	***3.97***	***4.67***	***6.01***	***7.26***	***8.20***	***8.83***	***9.20***	***9.21***	***Frequent Combination***
	s *b*	***20.51***	***19.79***	***19.11***	***17.34***	***15.62***	***14.38***	***16.70***	***14.27***	***12.48***	***11.24***	***10.44***	***10.34***	
Resultant (Inferior Prestress)	s *t*	***1.74***	***1.58***	***2.01***	***3.02***	***4.11***	***4.96***	***6.29***	***7.54***	***8.48***	***9.12***	***9.48***	***9.49***	
	s *b*	***17.15***	***16.35***	***15.57***	***13.51***	***11.42***	***9.82***	***11.23***	***8.77***	***6.95***	***5.69***	***4.92***	***4.57***	
Resultant (Superior Prestress)	s *t*	***1.94***	***1.71***	***2.00***	***2.67***	***3.34***	***3.84***	***5.00***	***6.08***	***6.90***	***7.46***	***7.79***	***7.80***	***Quasi Permanent***
	s *b*	***20.83***	***20.20***	***19.70***	***18.41***	***17.24***	***16.43***	***19.11***	***17.05***	***15.53***	***14.45***	***13.72***	***13.35***	

Resultant (Inferior Prestress)	s *t*	***1.72***	***1.52***	***1.86***	***2.65***	***3.48***	***4.13***	***5.29***	***6.37***	***7.19***	***7.75***	***8.08***	***8.09***	***nent Combination***
	s *b*	***17.19***	***16.49***	***15.89***	***14.31***	***12.77***	***11.60***	***13.37***	***11.27***	***9.72***	***8.64***	***7.93***	***7.57***	

		13--13	***14--14***	***15--15***	***16--16***	***17--17***	***18--18***	***19--19***	***20--20***	***21--21***	***22--22***	***23--23***	
Distance (x)		***25.7***	***28.7***	***31.7***	***34.7***	***37.7***	***40.2***	***42.7***	***42.7***	***47.2***	***47.9***	***48.4***	
Prestress	*s t*	*-1.44*	*-1.45*	*-1.44*	*-1.43*	*-1.41*	*-1.46*	*-0.70*	*0.10*	*0.74*	*0.96*	*1.11*	
	s b	*28.95*	*29.07*	*29.03*	*28.87*	*28.69*	*24.13*	*22.36*	*20.51*	*19.04*	*18.54*	*18.17*	
Dead Load	s t	*7.07*	*6.83*	*6.40*	*5.76*	*4.90*	*4.03*	*2.98*	*1.77*	*0.68*	*0.27*	*0.03*	
	s b	*-15.11*	*-14.59*	*-13.68*	*-12.31*	*-10.48*	*-8.61*	*-6.38*	*-3.79*	*-1.45*	*-0.58*	*-0.06*	
Temperature	s t	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	
	s b	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	
Crash Barrier	s t	*0.68*	*0.66*	*0.62*	*0.56*	*0.47*	*0.39*	*0.28*	*0.17*	*0.07*	*0.03*	*0.00*	
	s b	*-1.46*	*-1.41*	*-1.32*	*-1.19*	*-1.01*	*-0.82*	*-0.61*	*-0.36*	*-0.14*	*-0.06*	*0.00*	
Wearing Coat	s t	*0.91*	*0.88*	*0.82*	*0.74*	*0.63*	*0.51*	*0.38*	*0.22*	*0.09*	*0.04*	*0.00*	
	s b	*-1.94*	*-1.88*	*-1.76*	*-1.58*	*-1.34*	*-1.09*	*-0.81*	*-0.48*	*-0.19*	*-0.08*	*0.00*	
VLL	s t	*1.88*	*1.84*	*1.73*	*1.56*	*1.34*	*1.11*	*0.84*	*0.50*	*0.20*	*0.09*	*0.03*	
	s b	*-4.01*	*-3.92*	*-3.69*	*-3.34*	*-2.86*	*-2.37*	*-1.80*	*-1.06*	*-0.43*	*-0.18*	*-0.06*	
Tension due to Torsion	s t	*-0.15*	*-0.18*	*-0.21*	*-0.23*	*-0.25*	*-0.27*	*-0.30*	*-0.34*	*-0.34*	*-0.37*	*0.00*	
	s b	*-0.15*	*-0.18*	*-0.21*	*-0.23*	*-0.25*	*-0.27*	*-0.30*	*-0.34*	*-0.34*	*-0.37*	*0.00*	
Differential Shrinkage	s t	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	
	s b	*-0.18*	*-0.18*	*-0.18*	*-0.18*	*-0.18*	*-0.18*	*-0.18*	*-0.18*	*-0.18*	*-0.18*	*-0.18*	
Resultant (Superior Prestress)	s t	***9.80***	***9.43***	***8.80***	***7.86***	***6.61***	***5.27***	***4.57***	***3.64***	***2.75***	***2.37***	***2.56***	***Rare Combination***
	s b	***11.25***	***12.05***	***13.30***	***15.09***	***17.51***	***15.20***	***16.44***	***18.16***	***19.93***	***20.61***	***21.33***	
Resultant (Inferior Prestress)	s t	***10.08***	***9.72***	***9.08***	***8.14***	***6.89***	***5.56***	***4.71***	***3.62***	***2.60***	***2.18***	***2.34***	
	s b	***5.46***	***6.24***	***7.50***	***9.31***	***11.78***	***10.37***	***11.97***	***14.06***	***16.12***	***16.90***	***17.69***	
Resultant (Superior Prestress)	s t	***9.20***	***8.83***	***8.20***	***7.26***	***6.01***	***4.67***	***3.97***	***3.04***	***2.15***	***1.77***	***1.96***	***Frequent Combination***
	s b	***10.44***	***11.24***	***12.48***	***14.27***	***16.70***	***14.38***	***15.62***	***17.34***	***19.11***	***19.79***	***20.51***	
Resultant (Inferior Prestress)	s t	***9.48***	***9.12***	***8.48***	***7.54***	***6.29***	***4.96***	***4.11***	***3.02***	***2.01***	***1.58***	***1.74***	
	s b	***4.65***	***5.42***	***6.68***	***8.50***	***10.96***	***9.55***	***11.15***	***13.24***	***15.30***	***16.08***	***16.88***	

Resultant (Superior Prestress)	s t	***7.79***	***7.46***	***6.90***	***6.08***	***5.00***	***3.84***	***3.34***	***2.67***	***2.00***	***1.71***	***1.94***	***Quasi Permament Combination***
	s b	***13.45***	***14.18***	***15.26***	***16.78***	***18.84***	***16.15***	***16.97***	***18.14***	***19.43***	***19.92***	***20.56***	
Resultant (Inferior Prestress)	s t	***8.08***	***7.75***	***7.19***	***6.37***	***5.29***	***4.13***	***3.48***	***2.65***	***1.86***	***1.52***	***1.72***	
	s b	***7.66***	***8.37***	***9.45***	***11.00***	***13.10***	***11.33***	***12.50***	***14.04***	***15.62***	***16.22***	***16.92***	

6) DL + PS 23 Cables (After All Losses) + 2 Lane SIDL + 2 Lane VLL (Leading) + Temperature Fall (Accompanying)

Load factors as Per Table 3.3 of IRC 6-2016

Loads	*Rare Combination*	*Frequent Combination*	*Quasi Permanent Combination*
Dead Load	1	1	1
Superior Prestressing	1.1	1.1	1.1
Inferior Prestressing	0.9	0.9	0.9
Crash Barrier	1	1	1
Wearing Coat	1.2	1.2	1.2
VLL Leading	1	0.75	0
Temperature Fall	*0.6*	*0.5*	*0.5*
Differential Shrinkage	*1*	*1*	*1*

Minimum Allowable Compression = 0.5 Mpa (At joints)
Minimum Allowable Compression = 0 Mpa (At other locations)
Maximum Allowable Compression = 85 Mpa CL 3.1.6 NF P18 - 710
Maximum Allowable Compression = 54 Mpa (For Frequent and quasi permanent combination)

		1--1	***2--2***	***3--3***	***4--4***	***5--5***	***6--6***	***7--7***	***8--8***	***9--9***	***10--10***	***11--11***	***12--12***
Distance (x)		***0***	***0.5***	***1.2***	***3.2***	***5.7***	***8.2***	***10.7***	***13.7***	***16.7***	***19.7***	***22.7***	***24.2***
Prestress	s *t*	*1.11*	*0.96*	*0.74*	*0.10*	*-0.70*	*-1.46*	*-1.41*	*-1.43*	*-1.44*	*-1.45*	*-1.44*	*-1.44*
	s *b*	*18.17*	*18.54*	*19.04*	*20.51*	*22.36*	*24.13*	*28.69*	*28.87*	*29.03*	*29.07*	*28.95*	*28.88*
Dead Load	s *t*	*0.03*	*0.27*	*0.68*	*1.77*	*2.98*	*4.03*	*4.90*	*5.76*	*6.40*	*6.83*	*7.07*	*7.07*
	s *b*	*-0.06*	*-0.58*	*-1.45*	*-3.79*	*-6.38*	*-8.61*	*-10.48*	*-12.31*	*-13.68*	*-14.59*	*-15.11*	*-15.11*
Temperature Fall	s *t*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*
	s *b*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*
Crash Barrier	s *t*	*0.00*	*0.03*	*0.07*	*0.17*	*0.28*	*0.39*	*0.47*	*0.56*	*0.62*	*0.66*	*0.68*	*0.68*
	s *b*	*0.00*	*-0.06*	*-0.14*	*-0.36*	*-0.61*	*-0.82*	*-1.01*	*-1.19*	*-1.32*	*-1.41*	*-1.46*	*-1.46*
Wearing Coat	s *t*	*0.00*	*0.04*	*0.09*	*0.22*	*0.38*	*0.51*	*0.63*	*0.74*	*0.82*	*0.88*	*0.91*	*0.91*
	s *b*	*0.00*	*-0.08*	*-0.19*	*-0.48*	*-0.81*	*-1.09*	*-1.34*	*-1.58*	*-1.76*	*-1.88*	*-1.94*	*-1.94*
VLL	s *t*	*0.03*	*0.09*	*0.20*	*0.50*	*0.84*	*1.11*	*1.34*	*1.56*	*1.73*	*1.84*	*1.88*	*1.87*
	s *b*	*-0.06*	*-0.18*	*-0.43*	*-1.06*	*-1.80*	*-2.37*	*-2.86*	*-3.34*	*-3.69*	*-3.92*	*-4.01*	*-4.01*
Tension due to Torsion	s *t*	*0.00*	*-0.37*	*-0.34*	*-0.34*	*-0.30*	*-0.27*	*-0.25*	*-0.23*	*-0.21*	*-0.18*	*-0.15*	*-0.15*
	s *b*	*0.00*	*-0.37*	*-0.34*	*-0.34*	*-0.30*	*-0.27*	*-0.25*	*-0.23*	*-0.21*	*-0.18*	*-0.15*	*-0.15*
Differential Shrinkage	s *t*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*
	s *b*	*-0.18*	*-0.18*	*-0.18*	*-0.18*	*-0.18*	*-0.18*	*-0.18*	*-0.18*	*-0.18*	*-0.18*	*-0.18*	*-0.18*

Resultant (Superior Prestress)	s t	**2.09**	**1.92**	**2.32**	**3.29**	**4.30**	**5.06**	**6.46**	**7.77**	**8.75**	**9.41**	**9.79**	**9.79**	**Rare Combination**
	s b	**20.66**	**19.90**	**19.16**	**17.24**	**15.34**	**13.95**	**16.14**	**13.60**	**11.72**	**10.42**	**9.60**	**9.51**	
Resultant (Inferior Prestress)	s t	**1.87**	**1.72**	**2.18**	**3.27**	**4.44**	**5.36**	**6.74**	**8.05**	**9.04**	**9.70**	**10.07**	**10.08**	
	s b	**17.02**	**16.20**	**15.36**	**13.14**	**10.86**	**9.13**	**10.41**	**7.82**	**5.92**	**4.61**	**3.81**	**3.73**	
Resultant (Superior Prestress)	s t	**1.96**	**1.77**	**2.15**	**3.04**	**3.97**	**4.67**	**6.01**	**7.26**	**8.20**	**8.83**	**9.20**	**9.21**	**Frequent Combination**
	s b	**20.51**	**19.79**	**19.11**	**17.34**	**15.62**	**14.38**	**16.70**	**14.27**	**12.48**	**11.24**	**10.44**	**10.34**	
Resultant (Inferior Prestress)	s t	**1.74**	**1.58**	**2.01**	**3.02**	**4.11**	**4.96**	**6.29**	**7.54**	**8.48**	**9.12**	**9.48**	**9.49**	
	s b	**17.15**	**16.35**	**15.57**	**13.51**	**11.42**	**9.82**	**11.23**	**8.77**	**6.95**	**5.69**	**4.92**	**4.84**	
Resultant (Superior Prestress)	s t	**1.94**	**1.71**	**2.00**	**2.67**	**3.34**	**3.84**	**5.00**	**6.08**	**6.90**	**7.46**	**7.79**	**7.80**	**Quasi Permament Combination**
	s b	**20.83**	**20.20**	**19.70**	**18.41**	**17.24**	**16.43**	**19.11**	**17.05**	**15.53**	**14.45**	**13.72**	**13.62**	
Resultant (Inferior Prestress)	s t	**1.72**	**1.52**	**1.86**	**2.65**	**3.48**	**4.13**	**5.29**	**6.37**	**7.19**	**7.75**	**8.08**	**8.09**	
	s b	**17.19**	**16.49**	**15.89**	**14.31**	**12.77**	**11.60**	**13.37**	**11.27**	**9.72**	**8.64**	**7.93**	**7.85**	

		13--13	**14--14**	**15--15**	**16--16**	**17--17**	**18--18**	**19--19**	**20--20**	**21--21**	**22--22**	**23--23**	
Distance (x)		**25.7**	**28.7**	**31.7**	**34.7**	**37.7**	**40.2**	**42.7**	**42.7**	**47.2**	**47.9**	**48.4**	
Prestress	s t	-1.44	-1.45	-1.44	-1.43	-1.41	-1.46	-0.70	0.10	0.74	0.96	1.11	
	s b	28.95	29.07	29.03	28.87	28.69	24.13	22.36	20.51	19.04	18.54	18.17	
Dead Load	s t	7.07	6.83	6.40	5.76	4.90	4.03	2.98	1.77	0.68	0.27	0.03	
	s b	-15.11	-14.59	-13.68	-12.31	-10.48	-8.61	-6.38	-3.79	-1.45	-0.58	-0.06	
Temperature Fall	s t	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	
	s b	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	
Crash Barrier	s t	0.68	0.66	0.62	0.56	0.47	0.39	0.28	0.17	0.07	0.03	0.00	
	s b	-1.46	-1.41	-1.32	-1.19	-1.01	-0.82	-0.61	-0.36	-0.14	-0.06	0.00	
Wearing Coat	s t	0.91	0.88	0.82	0.74	0.63	0.51	0.38	0.22	0.09	0.04	0.00	
	s b	-1.94	-1.88	-1.76	-1.58	-1.34	-1.09	-0.81	-0.48	-0.19	-0.08	0.00	
VLL	s t	1.88	1.84	1.73	1.56	1.34	1.11	0.84	0.50	0.20	0.09	0.03	
	s b	-4.01	-3.92	-3.69	-3.34	-2.86	-2.37	-1.80	-1.06	-0.43	-0.18	-0.06	
Tension due to Torsion	s t	-0.15	-0.18	-0.21	-0.23	-0.25	-0.27	-0.30	-0.34	-0.34	-0.37	0.00	
	s b	-0.15	-0.18	-0.21	-0.23	-0.25	-0.27	-0.30	-0.34	-0.34	-0.37	0.00	
Differential Shrinkage	s t	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	
	s b	-0.18	-0.18	-0.18	-0.18	-0.18	-0.18	-0.18	-0.18	-0.18	-0.18	-0.18	
Resultant (Superior Prestress)	s t	**9.79**	**9.41**	**8.75**	**7.77**	**6.46**	**5.06**	**4.30**	**3.29**	**2.32**	**1.92**	**2.09**	**Rare Combination**
	s b	**9.60**	**10.42**	**11.72**	**13.60**	**16.14**	**13.95**	**15.34**	**17.24**	**19.16**	**19.90**	**20.66**	
Resultant (Inferior Prestress)	s t	**10.07**	**9.70**	**9.04**	**8.05**	**6.74**	**5.36**	**4.44**	**3.27**	**2.18**	**1.72**	**1.87**	
	s b	**3.81**	**4.61**	**5.92**	**7.82**	**10.41**	**9.13**	**10.86**	**13.14**	**15.36**	**16.20**	**17.02**	
Resultant (Superior Prestress)	s t	**9.20**	**8.83**	**8.20**	**7.26**	**6.01**	**4.67**	**3.97**	**3.04**	**2.15**	**1.77**	**1.96**	**Frequent Combination**
	s b	**10.44**	**11.24**	**12.48**	**14.27**	**16.70**	**14.38**	**15.62**	**17.34**	**19.11**	**19.79**	**20.51**	
Resultant (Inferior Prestress)	s t	**9.48**	**9.12**	**8.48**	**7.54**	**6.29**	**4.96**	**4.11**	**3.02**	**2.01**	**1.58**	**1.74**	
	s b	**4.65**	**5.42**	**6.68**	**8.50**	**10.96**	**9.55**	**11.15**	**13.24**	**15.30**	**16.08**	**16.88**	
Resultant (Superior	s t	**7.79**	**7.46**	**6.90**	**6.08**	**5.00**	**3.84**	**3.34**	**2.67**	**2.00**	**1.71**	**1.94**	

(Superior Prestress)	s b	13.45	14.18	15.26	16.78	18.84	16.15	16.97	18.14	19.43	19.92	20.56	Quasi Permament Combination
Resultant (Inferior Prestress)	s t	8.08	7.75	7.19	6.37	5.29	4.13	3.48	2.65	1.86	1.52	1.72	
	s b	7.66	8.37	9.45	11.00	13.10	11.33	12.50	14.04	15.62	16.22	16.92	

8) Check for Deflection at Midspan (From Midas Civil)

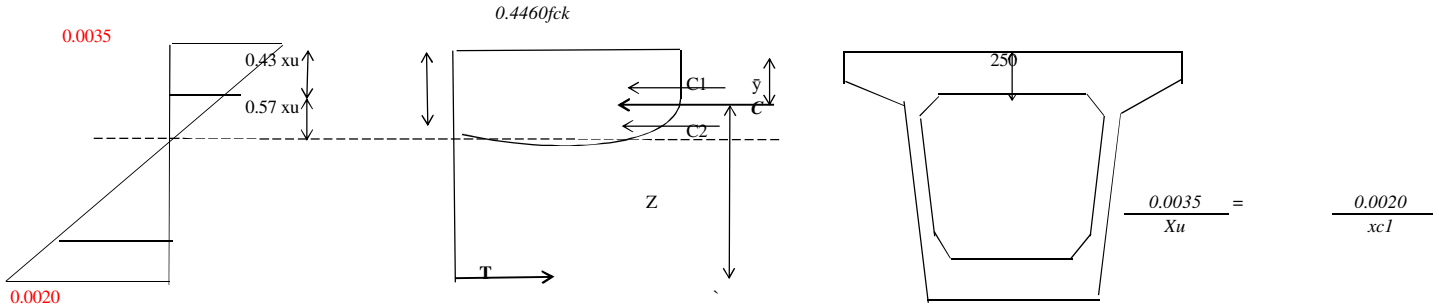
Loads	Deflections	Factor
Prestress =	85.60	1.00
Self weight =	-57.90	1.00
Crash Barrier =	-5.59	1.00
Wearing Coat =	-7.44	1.20
FPLL + VLL =	-14.38	0.75
Total =	**2.40** mm	

Permissible Deflection $= \frac{L}{800} = \frac{48400}{800} =$ **60.5** mm **Hence OK**

9) Ultimate moment capacity calculation

(i) Calculation of Neutral Axis Depth

Assuming Neutral axis lies within the top slab



Area of stress Block = 0.19 Xu + 0.17 Xu = 0.36 Xu

Moment of area about extream fibre = 0.15 xu^2

$\bar{y}$ = 0.42 Xu

C = T *C*= 0.36*fck*b.xu fck= *M150*

b= *17200* ***mm***

bw= *600* ***mm***

Sections	1--1	2--2	3--3	4--4	5--5	6--6	7--7	8--8	9--9	10--10	12--12
Node Number	8	12	15	16	17	18	19	20	21	22	23
T = Prestessing Force (after friction and Slip loss)	78801.23	78896.04	79023.21	79406.55	79863.51	80400.03	81379.84	81860.45	82267.62	82272.53	81641.93
Xu=	84.84	84.94	85.08	85.49	85.99	86.56	87.62	88.14	88.57	88.58	87.90
0.42 Xu =	35.29	35.33	35.39	35.56	35.77	36.01	36.45	36.66	36.84	36.85	36.56

Sections	14--14	15--15	16--16	17--17	18--18	19--19	20--20	21--21	22--22	23--23
Node Number	24	25	26	27	28	29	30	31	34	38
T = Prestessing Force (after friction and Slip loss)	82272.53	82267.62	81860.45	81379.84	80400.03	79863.51	79406.55	79023.21	78896.04	78801.23
Xu=	88.58	88.57	88.14	87.62	86.56	85.99	85.49	85.08	84.94	84.84
85.08 Xu =	36.85	36.84	36.66	36.45	36.01	35.77	35.56	35.39	35.33	35.29

Depth of neutral axis = *87.90 Neutral axis lies web*

$$Xumax/d = \frac{\varepsilon_{cp} + \varepsilon_{cu}}{\varepsilon_{cp} \pm \varepsilon_{cu} + \varepsilon_{spu} - \varepsilon_{sp\infty}}$$

ε_{cu} , Ultimate strain in concrete at top = ***0.0035***

ε_{cp} , Strain in concrete at top due to prestress

$\varepsilon_{spα}$, Locked in strain in HTS immediately after anchorage

ε_{spu}, Ultimate strain at the C.G of the HTS

P_{final} , Pre-stressing force after all losses

εcp	=	*M / (Zt . Ep)*	=	***0.00003***	
εspu	=	*fp / Ep*	=	***0.00955***	
εspα	=	*Po / (Ap.Ep)*	=	***0.006843***	

Therefore, Xumax/d = ***0.566*** < ***0.032*** ***Under reinforced section***

Ultimate Moment of resistance, Mur : For neutral axis in web

= 0.36 fck.bw.(d-xu).(d - 0.42 xu) + 0.446 fck.(btf). Df. (d - 0.5 Df)

= *971639.9547 kNm* > *165402.7 kNm* OK

10) Check for Ultimate Shear **As per IRC 112-2020 (Cl:10.3.2)**

Ultimate Shear Check due to external loads:

	Section at	*Support*	*1st Junction*	*2nd Junction*	*3rd Junction*	*4th Junction*	*5th Junction*	*6th Junction*	*7th Junction*	*8th Junction*	*9th Junction*	*10th Junction*	*L/2*
	Distance from support	***0***	***0.5***	***1.2***	***3.2***	***5.7***	***8.2***	***10.7***	***13.7***	***16.7***	***19.7***	***22.7***	***22.7***
Combination 1 :- (DL + SIDL + WC + 4 Lane VLL) - Shear Due to Prestress													
(as per Cl:10.3.2 (5) of IRC 112)			**Factored**										
	Dead Load (kN)	7901.82	7724.81	7476.98	6768.90	5883.81	4991.18	4170.70	3245.28	2319.85	1394.43	469.00	6.29
	CB (kN)	738.34	723.09	701.73	640.71	564.44	488.16	411.89	320.36	228.83	137.30	45.77	0.00
	WC (kN)	1270.50	1244.25	1207.50	1102.50	971.25	840.00	708.75	551.25	393.75	236.25	78.75	0.00
	FPLL (kN)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	VLL (kN)	2489.46	2489.46	2297.64	2265.57	2021.09	1844.19	1700.43	1556.69	1403.13	1193.42	981.68	981.68
	Shear due to prestress (kN)	3889.90	3753.40	3509.80	2901.50	2161.30	2830.90	3850.00	0.00	0.00	0.00	0.00	0.00
	Special Vehicle (kN)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total (kN)	8510.22	8428.21	8174.05	7876.18	7279.28	5332.63	3141.77	5673.57	4345.56	2961.39	1575.19	987.97
	V_{ED} (kN)=	**8510.22**	**8428.21**	**8174.05**	**7876.18**	**7279.28**	**5332.63**	**3141.77**	**5673.57**	**4345.56**	**2961.39**	**1575.19**	**987.97**
Shear per Outer Web			**Factored**										
	Dead Load (kN)	2607.60	2549.19	2467.40	2233.74	1941.66	1647.09	1376.33	1070.94	765.55	460.16	154.77	2.08
	CB (kN)	243.65	238.62	231.57	211.43	186.26	161.09	135.92	105.72	75.51	45.31	15.10	0.00
	WC (kN)	419.27	410.60	398.48	363.83	320.51	277.20	233.89	181.91	129.94	77.96	25.99	0.00
	FPLL (kN)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	VLL (kN)	821.52	821.52	758.22	747.64	666.96	608.58	561.14	513.71	463.03	393.83	323.95	323.95
	Shear due to prestress (kN)	777.98	750.68	701.96	580.30	432.26	566.18	770.00	0.00	0.00	0.00	0.00	0.00
	Special Vehicle (kN)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total (kN)	3314.06	3269.25	3153.71	2976.33	2683.13	2127.78	1537.28	1872.28	1434.03	977.26	519.81	326.03
	V_{ED} (kN)=	**3314.06**	**3269.25**	**3153.71**	**2976.33**	**2683.13**	**2127.78**	**1537.28**	**1872.28**	**1434.03**	**977.26**	**519.81**	**326.03**
Shear per Inner Web			**Factored**										
	Dead Load (kN)	2607.60	2549.19	2467.40	2233.74	1941.66	1647.09	1376.33	1070.94	765.55	460.16	154.77	2.08
	CB (kN)	243.65	238.62	231.57	211.43	186.26	161.09	135.92	105.72	75.51	45.31	15.10	0.00
	WC (kN)	419.27	410.60	398.48	363.83	320.51	277.20	233.89	181.91	129.94	77.96	25.99	0.00
	FPLL (kN)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	VLL (kN)	821.52	821.52	758.22	747.64	666.96	608.58	561.14	513.71	463.03	393.83	323.95	323.95
	VLL with congestion factor (kN)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Shear due to prestress (kN)	1555.96	1501.36	1403.92	1160.60	864.52	1132.36	1540.00	0.00	0.00	0.00	0.00	0.00
	Special Vehicle (kN)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total (kN)	2536.08	2518.57	2451.75	2396.03	2250.87	1561.60	767.28	1872.28	1434.03	977.26	519.81	326.03
	VED (kN)=	**2536.08**	**2518.57**	**2451.75**	**2396.03**	**2250.87**	**1561.60**	**767.28**	**1872.28**	**1434.03**	**977.26**	**519.81**	**326.03**
Shear per Web			**Factored**										
	Dead Load (kN)	2607.60	2549.19	2467.40	2233.74	1941.66	1647.09	1376.33	1070.94	765.55	460.16	154.77	2.08
	Rear Trolley (kN)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Shear due to prestress (kN)	972.48	938.35	877.45	725.38	540.33	707.73	962.50	0.00	0.00	0.00	0.00	0.00
	Total (kN)	1635.13	1610.84	1589.95	1508.36	1401.33	939.36	413.83	1070.94	765.55	460.16	154.77	2.08
	VED (kN)=	**1635.13**	**1610.84**	**1589.95**	**1508.36**	**1401.33**	**939.36**	**413.83**	**1070.94**	**765.55**	**460.16**	**154.77**	**2.08**

Combination 1 :- (DL + SIDL + WC + 3 Lane VLL/SPL VLL) - Shear Due to Prestress														
Shear due to Torsion (As per Cl:10.5.2 of IRC 112)	According to IRC:112-2020, CL:10.5.2.1 (1) & EN 1992-1-1 2004 CL 6.3.2, to find the "Design Torsional Shear Force"													
	Shear stress ($t_{t,i}$)													
	f_{ck} = characteristic	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	Mpa
	f_{cd} = Design values of Compressive Strength	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	Mpa
	Torsional Moment in kN-m = TED	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	kNm

u = perimeter	0.0	0.0	0.0	0.0	0.0	0.0	0.0						m
Ac = Area of C/s	0.0	0.0	0	0.0	0.0	0	0.0						mm^2
teff,i = A/u	934.930	934.930	934.930	934.930	934.930	934.930	934.930	934.930	934.930	934.930	934.930	934.930	mm
Ak = Area within cl of walls =	15953248	15953248	15953248	15953248	15953248	15953248	15953248	15953248	15953248	15953248	15953248	15953248	mm^2

Calculation of Ak and perimeter

	End section	Running section
Bottom Length (mm) =	5253.83	5253.83
Web length (mm) =	5673.27	5673.27
Top Length (mm) =	15452.04	15452.04
Area (Ak) =	15953248	15953248
Perimeter =	17063.57	17063.57

5673 2712

d	2712.0	2712.0	2712.0	2712.0	2712.0	2712.0	2712.0	2712.0	2712.0	2712.0	2712.0	2712.0	mm
$\tau_{t,i}$	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	Mpa
$V_{Ed,i}$	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	kN
Total Design shear Force= $V_{Ed} + V_{Ed,i}$	**2978.4**	**2924.1**	**2861.0**	**2659.1**	**2401.6**	**1787.9**	**1122.9**	**1622.6**	**1159.9**	**697.2**	**234.5**	**3.1**	kN

Combination 1 :- (DL + SIDL + WC + 4 Lane VLL/SPL VLL) - Shear Due to Prestress

Shear due to Torsion (As per Cl:10.5.2 of IRC 112)

According to IRC:112-2020, Cl:10.5.2.1 (1) & EN 1992-1-1 2004 CL 6.3.2, to find the "Design Torsional Shear Force"

Shear stress ($t_{t,i}$)													
f_{ck} = characteristic	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	Mpa
f_{cd} = Design values of Compressive	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	Mpa
Torsional Moment in kNm ... TED	2053.80	2053.80	1895.55	1869.10	1667.40	1521.46	1402.85	1284.27	1157.58	984.57	809.88	809.88	kNm
teff,i = A/u	934.930	934.930	934.930	934.930	934.930	934.930	934.930	934.930	934.930	934.930	934.930	934.930	mm
Ak = Area within cl of walls =	15953248	15953248	15953248	15953248	15953248	15953248	15953248	15953248	15953248	15953248	15953248	15953248	mm^2

Calculation of Ak and perimeter

	End section	Running section
Area (Ak) =	15953248.37	15953248.37
Perimeter =	17063.57	17063.57

d	2712.0	2712.0	2712.0	2712.0	2712.0	2712.0	2712.0	2712.0	2712.0	2712.0	2712.0	2712.0	mm
$\tau_{t,i}$	0.069	0.069	0.064	0.063	0.056	0.051	0.047	0.043	0.039	0.033	0.027	0.027	Mpa
$V_{Ed,i}$	**174.6**	**174.6**	**161.1**	**158.9**	**141.7**	**129.3**	**119.2**	**109.2**	**98.4**	**83.7**	**68.8**	**68.8**	kN
Total Design shear Force= $V_{Ed} + V_{Ed,i}$	**3488.6**	**3443.8**	**3314.8**	**3135.2**	**2824.9**	**2257.1**	**1656.5**	**1981.4**	**1532.4**	**1060.9**	**588.7**	**394.9**	kN

Maximum Shear Per Web

Total Design shear Force in Inner web =	2536.1	2518.6	2451.7	2396.0	2250.9	1561.6	767.3	1872.3	1434.0	977.3	519.8	kN
Total Design shear Force in Outer web =	3488.6	3443.8	3314.8	3135.2	2824.9	2257.1	1656.5	1981.4	1532.4	1060.9	588.7	kN

10.1) Shear Capacity per Web

		Outer Webs	Inner Web	
Section Web Width	b_w	**300**	**300**	mm
Section Web Depth	hw	**1724**	**2275**	mm
Effective Section Depth	d	1508.5	1990.625	mm
	z	1357.65	1791.5625	mm
Axial Force in the cross-section	N_{Ed}	**76065**	**76065**	kN
Design Shear Force	V_{Ed}	**3488.6**	**2536.1**	kN
Section 6.2.1.2	$\gamma_{cf}.\gamma_E$	**1.5**	**1.5**	
Elastic Modulus	E_c	**47270**	**47270**	MPa
Characteristic compressive strength	f_{ck}	**150**	**150**	MPa
Inclination of principal compression strut w.r.t. CG Longitudinal Axis of the section	θ	**30**	**30**	degrees

$\sigma_{cp} = N_{Ed} / A_c$

$$k = 1 + 3 \cdot \frac{\sigma_{cp}}{f_{ck}}$$

UHPFRC Contribution, $V_{Rd,c}$

Area of cross-section of UHPFRC	A_c	9558030	9558030	mm^2
Equation 6.203	σ_{cp}	7.96	7.96	MPa
Equation 6.202	k	1.16	1.16	
Equation 6.205	$V_{Rd,c}$	**925**	**1221**	**kN**

$$V_{Rd,c} = \frac{0.24}{\gamma_{cf}\gamma_E} k f_{ck}^{1/2} b_w z$$

Shear Rebar Contribution, $V_{Rd,s}$

Spacing	s	**100**	**100**	mm
Rebar Dia	φ	**0**	**0**	mm
Number of legs	N_{legs}	**1**	**1**	
C/S Area of shear reinforcement	A_{sw}	0.0	0.0	mm^2

Design elastic limit of shear rebar	$f_{y,wd}$	435	435	MPa
Angle of Inclination of Stirrups on long. Axis	α	90	**90**	degrees
Equation 6.208	**$V_{Rd,s}$**	**0**	**0**	**kN**

$$V_{Rd,s} = \frac{A_{sw}}{S} z f_{ywd} (\cot\theta + \cot\alpha)\sin\alpha$$

Fibre Contribution

C/S Area of section	A_{fv} = bw x z	407295	537468.75	mm^2
Orientation factor associated with local effects	K_{local}	1.75	1.75	NF P18-470 UHPC
Orientation factor associated with global effects	K_{global}	1.25	1.25	NF P18-470 UHPC
Characterstic post-cracking tensile strength	$f_{ctfk}/K.\Upsilon_{cf}$	**6.15**	**6.15**	MPa
Characteristic value of the tensile yield strength	$f_{ctk,el}/\Upsilon_{cf}$	**6.15**	**6.15**	MPa
Partial coefficient relating to the tensioned UHPC	γ_{cf}	1.3	1.3	
Maximum crack width	w	0.3	0.3	mm
Post cracking along shear crack of inclination θ	$\sigma_{Rd,f}$	6.15	6.15	MPa
Equation 6.209	$V_{Rd,f}$	4339	5725	kN

$$V_{Rdf} = A_{fv}\sigma_{Rdf}\cot\theta$$

Shear Strength= UHPFRC + Rebar + Fibre

		1775		
Shear Strength	**V_{Rd}**	**5264**	**6946**	**kN**
	V_{Ed}	**3489**	**2536**	**kN**
		OK	**OK**	

Shear Resistance Limitation

	αcc	0.85		
	Υ_c	1.5		
	Factor 1	1.73		
	Factor 2	4.00		
	Factor 3	0.58		
	$V_{Rd,max}$	**8652**	**kN**	
	$V_{Rd,Total}$	**8652**	kN	
D/C Ratio	**$V_{Ed}/V_{Rd,Total}$**	**0.403**		

$$V_{Rd,max} = 2.3\frac{\alpha_{cc}}{\gamma_C} b_w z f_{ck}^{2/3}\left[\frac{V_{Rd,s}(\cot\theta+\cot\alpha)}{(1+\cot^2\theta)} + V_{Rd,f}\tan\theta\right]\left[\frac{1}{V_{Rd,s}+V_{Rd,f}}\right]$$

Longitudinal tensile force due to strut action

	Factor 4	1.15	
	Factor 5	1.73	
Additional longitudinal tensile force (Eq 6.218)	**ΔF_{td}**	**2014**	**kN**

$$\Delta F_{td} = 0.5\ V_{Ed}\ [V_{Rd,f}\ (\cot\theta - \tan\theta) + V_{Rd,s}\ (\cot\theta - \cot\alpha)]\ /\ (V_{Rd,s} + V_{Rd,f})\ \geq 0$$

Resistance to Shear Buckling (As per cl. 509.4.2)

Shear resistance to Web buckling shall be verified,

if, d/t_w $> 67\varepsilon$ for a web without stiffeners

$\varepsilon = \sqrt{250/fy} =$ 1.715

$67\varepsilon =$ 114.904

$d/t_w =$ 13.560

Verification of Shear Buckling Not Required

Kv = 5.35 When transverse stiffners are provided only at supports

$V_n = V_{cr}$

Vcr= Shear Force corresponding to Web buckling

τ_{cre} = Elastic Critical Shear Stress of the Web

$$\tau_{cre} = \frac{Kv\pi^2E}{12(1-\mu^2)(d/t_w)^2}$$

$\tau_{cre} =$ 1178.33 N/mm^2

Non Dimensional Web Slenderness ratio for shear buckling stress(λw)

$\lambda_w = \sqrt{f_{yw}/(\sqrt{3} * \tau_{cre})}$

$\lambda_w =$ 0.20

Vcr= Av x τ_b

$\tau_b =$ $f_{yw}/\sqrt{3}$ if $\lambda_w \leq 0.8$

$(1-0.8(\lambda_w-0.8))*f_{yw}/\sqrt{3}$ if $0.8 < \lambda_w < 1.2$

$f_{yw}/(\sqrt{3}\lambda_w^2)$ if $\lambda_w \geq 1.2$

Hence, $\tau_b =$ 49.07 N/mm^2

$V_{cr} =$ **19987.91** kN > **3488.63** kN

Hence OK

Combination 1 :- (DL + SIDL + WC + 4 Lane VLL/SPL VLL) - Shear Due to Prestress

Shear due to Torsion (As per Cl:10.5.2 of IRC 112)

According to IRC:112-2011, Cl:10.5.2.1 (1) & EN 1992-1-1 2004 CL 6.3.2, to find the "Design Torsional Shear Force"

Shear stress ($t_{t,i}$)

Node Number	8	9	10	11	12	13	14	15	16	17	18	19	
f_{ck} = characteristic	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	Mpa
f_{cd} = Design values	67.0	67.0	67.0	67.0	67.0	67.0	67.0	67.0	67.0	67.0	67.0	67.0	Mpa
Torsional Moment in kNm — TED	1369.20	1369.20	1263.70	1246.06	1111.60	1014.30	935.24	856.18	771.72	656.38	539.92	539.92	kNm
teff,i = A/u	934.930	934.930	934.930	934.930	934.930	934.930	934.930	934.930	934.930	934.930	934.930	934.930	mm
Ak = Area within cl of walls	15953248	15953248	15953248	15953248	15953248	15953248	15953248	15953248	15953248	15953248	15953248	15953248	mm2

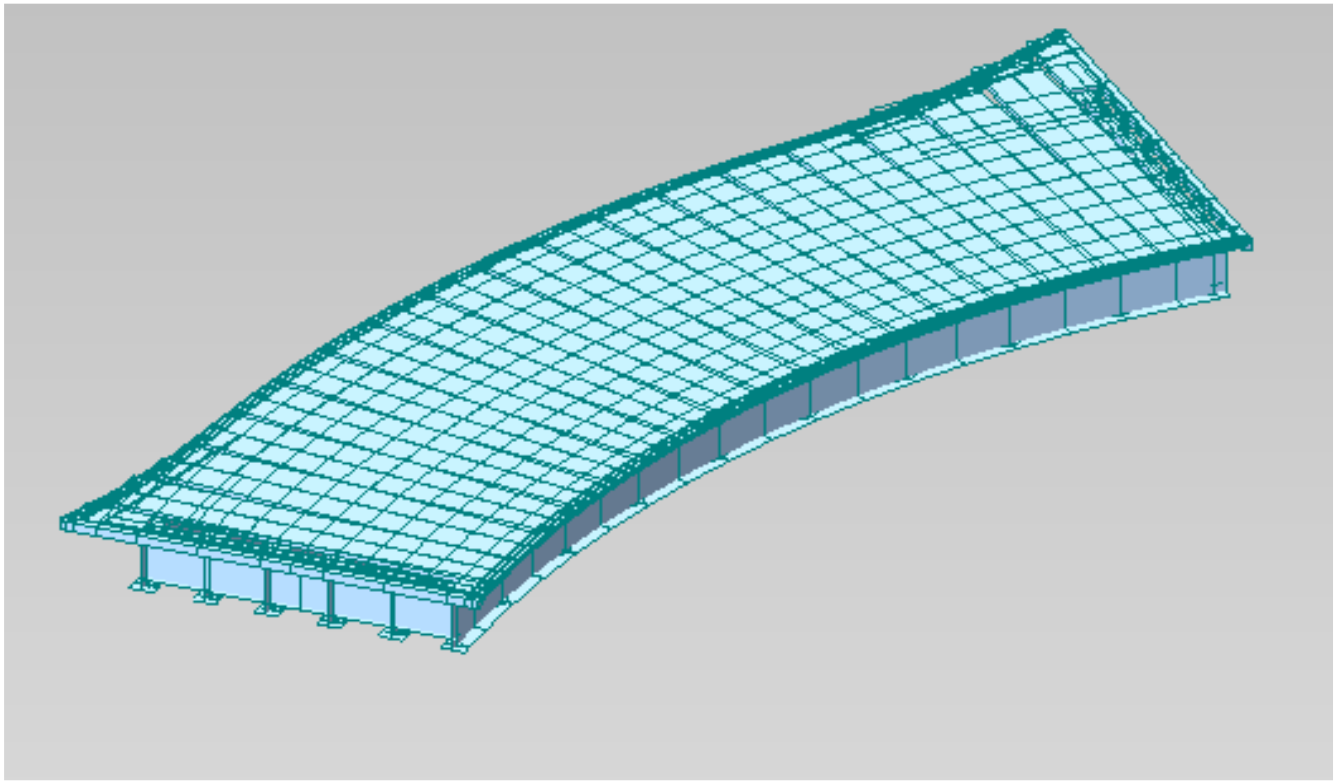
Calculation of Ak and perimeter

				End section	Running section								
		Area (Ak) =		15953248.37	15953248.37								
		Perimeter =		17063.57	17063.57								
d	2712.0	2712.0	2712.0	2712.0	2712.0	2712.0	2712.0	2712.0	2712.0	2712.0	2712.0	2712.0	mm
$\tau_{t,i}$	0.046	0.046	0.042	0.042	0.037	0.034	0.031	0.029	0.026	0.022	0.018	0.018	Mpa
$V_{Ed,i}$	**116.4**	**116.4**	**107.4**	**105.9**	**94.5**	**86.2**	**79.5**	**72.8**	**65.6**	**55.8**	**45.9**	**45.9**	kN
Web Area	**630147.5**	**630147.5**	**630147.5**	**630147.5**	**630147.5**	**630147.5**	**630147.5**	**630147.5**	**630147.5**	**630147.5**	**630147.5**	**630147.5**	**mm^2**
Touv	**0.185**	**0.185**	**0.170**	**0.168**	**0.150**	**0.137**	**0.126**	**0.115**	**0.104**	**0.089**	**0.073**	**0.073**	*Mpa*
Tension due to torsion	**0.369**	**0.369**	**0.341**	**0.336**	**0.300**	**0.274**	**0.252**	**0.231**	**0.208**	**0.177**	**0.146**	**0.146**	*Mpa*

Tension due to torsion = **Sqrt(4 x Touv ^ 2)**

Preliminary Design of Rotary Superstructure

Design of Composite Super Structure



General Design Data

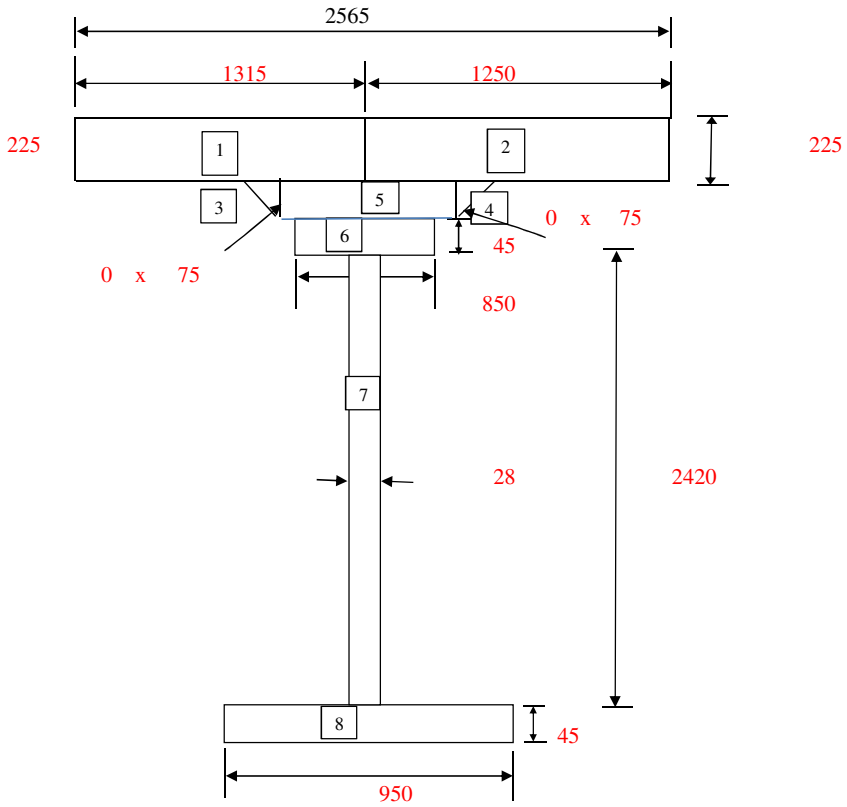
Effective span (C/C of bearing)	=	51.3	m	
Total Width of deck slab (Standard Span)	=	15	m	
Thickness of slab	=	0.263	m	(including average depth of concrete in decking sheet)
Width of carraigeway (Standard Span)	=	14	m	
C/C distance between girders (Skew Span)	=	2.5	m	

C/C distance between girders (Standard Span)		=	2.5	m	
Maximum Yield stress of steel	f_y	=	350	N/mm^2	(As per Table 2, IS: 2062-2011)
Grade of concrete	f_{ck}	=	40	N/mm^2	
Unit weight of concrete		=	25	kN/m^3	
Unit weight of steel		=	78.5	kN/m^3	
Modulus of Elasticity of concrete	Ecm	=	34000	N/mm^2	(As per Table- III.I, Anneure-I,IRC:22-2015)
Modulus of Elasticity of steel	Es	=	200000	N/mm^2	(As per IRC : 22-2015, Cl.604.3)
Modular ratio for permanent or long term loads	m	=	15		(As per IRC : 22-2015, Cl.604.3)
Modular ratio for transient loads	m	=	7.5		(As per IRC : 22-2015, Cl.604.3)
Spacing of the Cross Frame		=	5.470	m c/c	
Load due to wearing coat		=	2	kN/m^2	
Load due to crash barrier		=	8	kN/m	

Outer Girder is considered for the design calculations

2a) CALCULATION OF SECTION PROPERTIES

1) END GIRDER



Haunch Width= 700

a) For Dead load

Modular ratio m = 15 (Refer IRC : 22-2015, Cl.604.3)

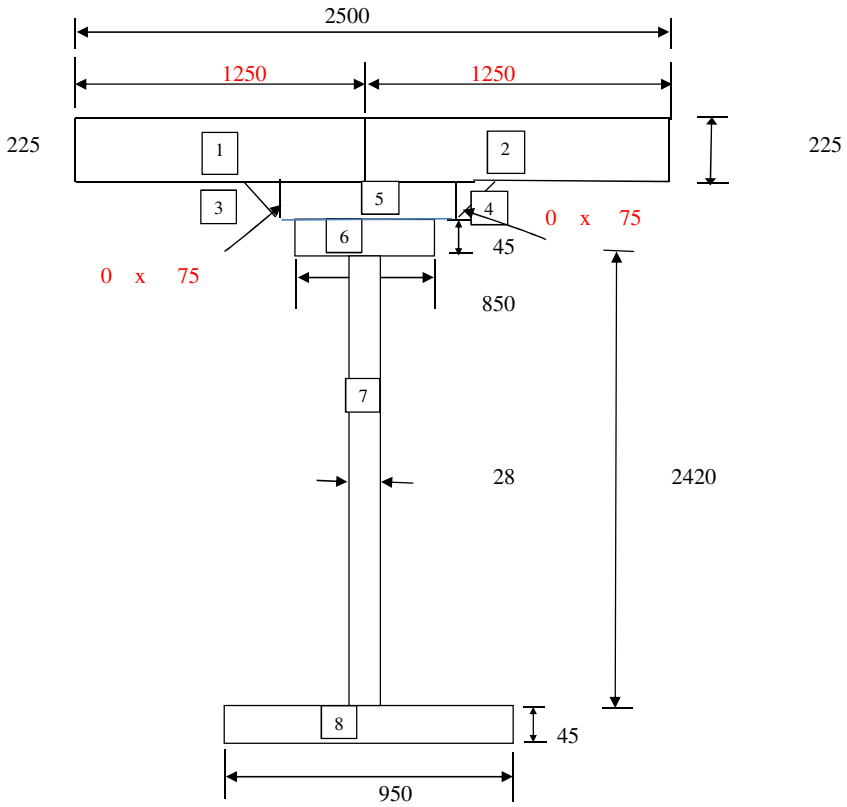
S No	Shape	B(mm)	D(mm)	Area	Y1 from top flange	AY	ybar	Iself	Aybar^2	Iz
1	Rectangle	87.67	225	19725.0	112.5	2219062.5	1156.9	83214844	26399384908	26482599752
2	Rectangle	83.33	225	18750.0	112.5	2109375.0	1156.9	79101563	25094472346	25173573908
3	Triangle	0	75	0.0	250.0	0.0	1019.4	0	0	0
4	Triangle	0.00	75	0.0	250.0	0.0	1019.4	0	0	0
5	Rectangle	46.67	75	3500.0	262.5	918750.0	1006.9	1640625	3548327267	3549967892
6	Rectangle	850	45	38250.0	322.5	12335625.0	946.9	6454688	34294267747	34300722435
7	Rectangle	28	2420	67760.0	1555.0	105366800.0	-285.6	33069138667	5527769664	38596908331
8	Rectangle	950	45	42750.0	2787.5	119165625	-1518.1	7214063	98525396897	98532610960
				190735.0		**242115238**				**2.26636E+11**
	Ytop =	**1269.38**	mm		**Ztop =**	**178540975**	mm^3	**Ztop for top Flange =**	**233795137.4**	mm^3
	Ybot =	**1540.62**	mm		**Zbot =**	**147107279.3**	mm^3			

b) **For Vehicular Live load**

Modular ratio m = 7.5 (Refer IRC : 22-2015, Cl.604.3)

S No	Shape	B(mm)	D(mm)	Area	Y1 from top flange	AY	ybar	Iself	Aybar^2	Iz
1	Rectangle	175.33	225	39450.00	112.5	4438125	950.46	166429687.50	35638435996	35804865684
2	Rectangle	166.67	225	37500.00	112.5	4218750	950.46	158203125.00	33876840301	34035043426
3	Triangle	0.00	75	0.00	250.00	0	812.96	0.00	0	0
4	Triangle	0.00	75	0.00	250.00	0	812.96	0.00	0	0
5	Rectangle	93.33	75	7000.00	262.5	1837500	800.46	3281250.00	4485201801	4488483051
6	Rectangle	850	45	38250	322.5	12335625	740.46	6454687.50	20971992937	20978447625
7	Rectangle	28	2420	67760	1555	105366800	-492.04	3.3069E+10	16404636267	49473774933
8	Rectangle	950	45	42750	2787.5	119165625	-1724.54	7214062.50	1.27139E+11	1.27147E+11
				232710.00		**247362425**				**2.71927E+11**
	Ytop =	**1062.96**	mm		**Ztop =**	**2.56E+08**	mm^3	**Ztop for top Flange =**	**356408972.7**	mm^3
	Ybot =	**1747.04**	mm		**Zbot =**	**1.56E+08**	mm^3			

2) INTERNAL GIRDER



Haunch Width= 700

a) For Dead load

Modular ratio m = 15 (Refer IRC : 22-2015, Cl.604.3)

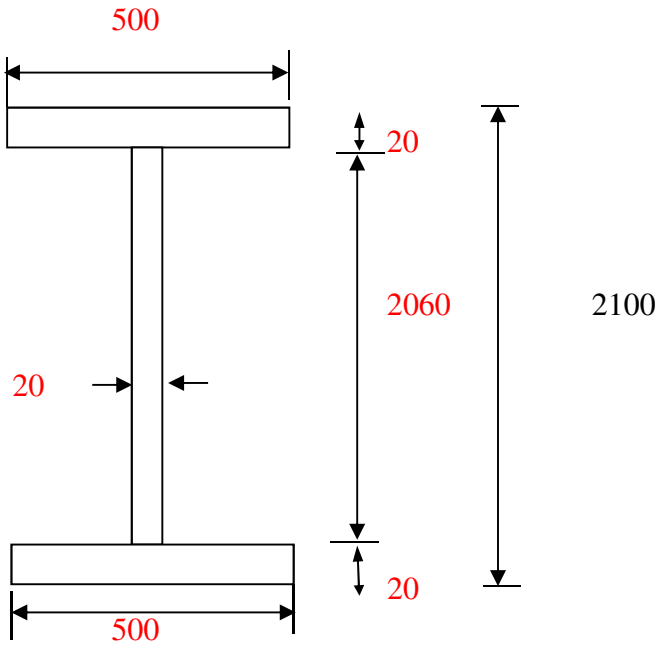
S No	Shape	B(mm)	D(mm)	Area	Y1 from top flange	AY	ybar	Iself	Aybar^2	Iz
1	Rectangle	83.33	225	18750.0	112.5	2109375.0	1162.8	79101563	25353009102	25432110664
2	Rectangle	83.33	225	18750.0	112.5	2109375.0	1162.8	79101563	25353009102	25432110664
3	Triangle	0	75	0.0	250.0	0.0	1025.3	0	0	0
4	Triangle	0	75	0.0	250.0	0.0	1025.3	0	0	0
5	Rectangle	46.67	75	3500.0	262.5	918750.0	1012.8	1640625	3590346124	3591986749
6	Rectangle	850	45	38250.0	322.5	12335625.0	952.8	6454688	34726190271	34732644958
7	Rectangle	28	2420	67760.0	1555.0	105366800.0	-279.7	33069138667	5300083205	38369221871
8	Rectangle	950	45	42750.0	2787.5	119165625	-1512.2	7214063	97755363733	97762577795
				189760.0		**242005550**				**2.25321E+11**
	Ytop =	**1275.32**	mm		**Ztop =**	**176677134.3**	mm^3	**Ztop for top Flange =**	**231021250.6**	
	Ybot =	**1534.68**	mm		**Zbot =**	**146819722.9**	mm^3			

b) **For Vehicular Live load**

Modular ratio m = 7.5 (Refer IRC : 22-2015, Cl.604.3)

S No	Shape	B(mm)	D(mm)	Area	Y1 from top flange	AY	ybar	Iself	Aybar^2	Iz
1	Rectangle	166.67	225	37500.00	112.5	4218750	958.50	158203125.00	34451800888	34610004013
2	Rectangle	166.67	225	37500.00	112.5	4218750	958.50	158203125.00	34451800888	34610004013
3	Triangle	0.00	75	0.00	250.00	0	821.00	0.00	0	0
4	Triangle	0.00	75	0.00	250.00	0	821.00	0.00	0	0
5	Rectangle	93.33	75	7000.00	262.5	1837500	808.50	3281250.00	4575661114	4578942364
6	Rectangle	850	45	38250	322.5	12335625	748.50	6454687.50	21429422758	21435877445
7	Rectangle	28	2420	67760	1555	105366800	-484.00	3.3069E+10	15873445221	48942583888
8	Rectangle	950	45	42750	2787.5	119165625	-1716.50	7214062.50	1.25958E+11	1.25965E+11
				230760.00		**247143050**				**2.70143E+11**
	Ytop =	**1071.00**	mm		**Ztop =**	**2.52E+08**	mm^3	**Ztop for top Flange =**	**350381322.9**	
	Ybot =	**1739.00**	mm		**Zbot =**	**1.55E+08**	mm^3			

2b) PROPERTIES FOR END CROSS GIRDER



For Dead load

Modular ratio m = 15 (Refer IRC : 22-2015, Cl.604.3)

S No	Shape	B(mm)	D(mm)	Area	Y1	AY	ybar	Iself	Aybar^2	Iz
1	Rectangle	33.333	0	0	0	0	1050	0	0	0
2	Rectangle	500	20	10000	10	100000	1040	333333.3	1.08E+10	10816333333
3	Rectangle	20	2060	41200	1050	43260000	0	14569693333.3	0	14569693333
4	Rectangle	500	20	10000	2090	20900000	-1040	333333.3	1.08E+10	10816333333
				61200		**64260000**				**36202360000**

	Ytop =	**1050**	mm		**Ztop =**	**34478438.1**	mm^3			

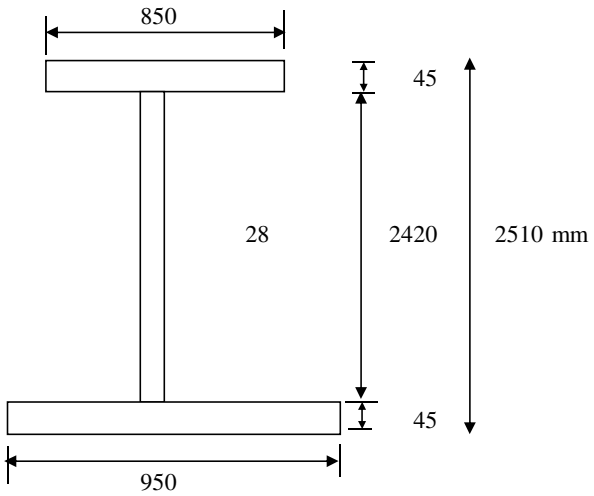
0.03620236

For Vehicular Live load

Modular ratio m = 7.5 (Refer IRC : 22-2015, Cl.604.3)

S No	Shape	B(mm)	D(mm)	Area	Y1	AY	ybar	Iself	Aybar^2	Iz
1	Rectangle	66.667	0	0	0	0	1050	0	0	0
2	Rectangle	500	20	10000	10	100000	1040	333333.3	1.08E+10	10816333333
3	Rectangle	20	2060	41200	1050	43260000	0	14569693333	0	14569693333
4	Rectangle	500	20	10000	2090	20900000	-1040	333333.3	1.08E+10	10816333333
				61200		**64260000**				**36202360000**
	Ytop =	**1050**	mm		**Ztop =**	**34478438.1**	mm^3			

2c) PROPERTIES FOR GIRDER WITHOUT COMPOSITE



S No	Shape	B(mm)	D(mm)	Area	Y1	AY	ybar	Iself	Aybar^2	Iz	I_Y
1	Rectangle	850	45	38250	22.5	860625	1269.78	6454687.5	61672364357	61678819044	2302968750
2	Rectangle	28	2420	67760	1255	85038800	37.28	33069138667	94188946.94	33163327614	4426986.667
3	Rectangle	950	45	42750	2487.5	106340625	-1195.22	7214062.50	61070220955	61077435017	3215156250
				148760		**192240050**				**1.5592E+11**	**5522551987**
	Ytop =	**1292.283**	mm		**Ztop =**	**120654343.2**	mm^3				
	Ybot =	**1217.717**	mm		**Zbot =**	**128042565.1**	mm^3				

3) DESIGN OF COMPOSITE GIRDER

1 Input

Effective span (C/C of bearing)		=	51.30 m	
Total Width of deck slab		=	15 m	
Thickness of slab		=	0.263 m	
Width of carraigeway (Straight Span)		=	7.5 m	
C/C distance between girders (Straight Span)		=	2.25 m	

2 Material Properties

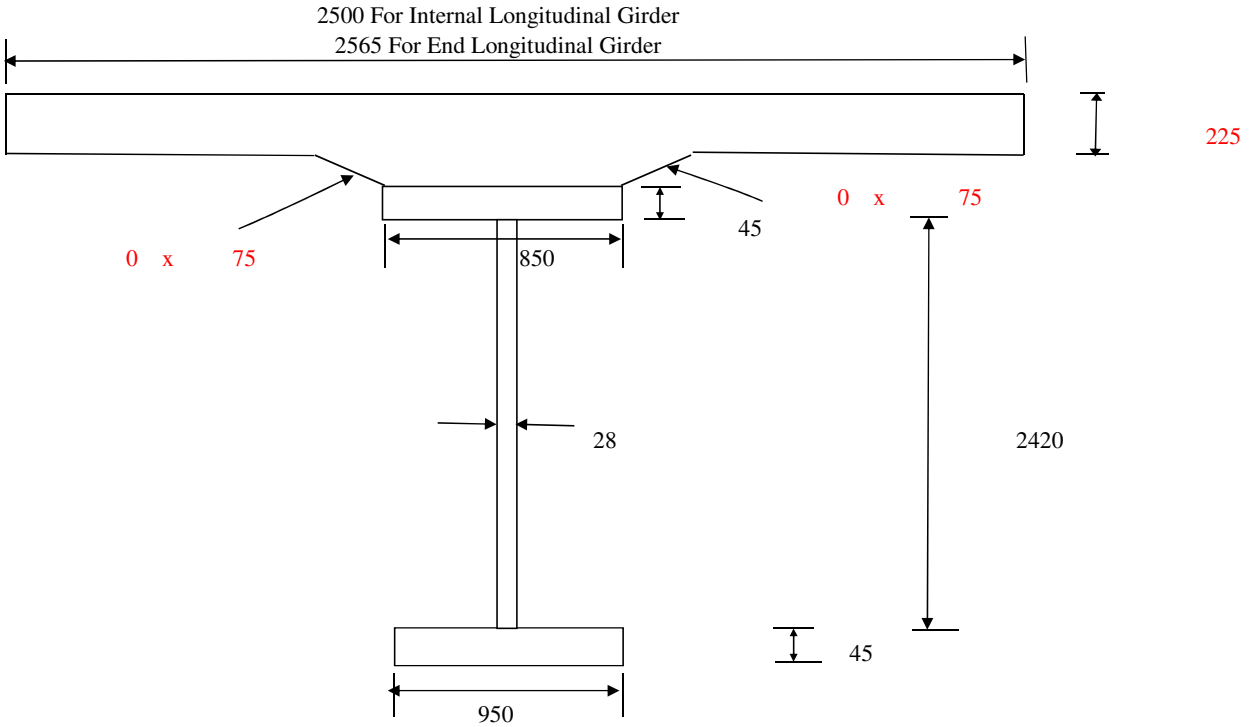
Yield stress of steel	f_y	=	350 N/mm^2	(As per Table 2, IS: 2062-2011)
Grade of concrete	f_{ck}	=	35 N/mm^2	
Unit weight of concrete		=	25 kN/m^3	
Unit weight of steel		=	78.5 kN/m^3	
Modulus of Elasticity of concrete	Ecm	=	34000 N/mm^2	(As per Table- III.I, Annexure-I,IRC:22-2015)
Modulus of Elasticity of steel	Es	=	200000 N/mm^2	(As per IRC : 22-2015, Cl.604.3)
Modular ratio for permanent or long term loads	m	=	15	(Refer IRC : 22-2015, Cl.604.3)
Modular ratio for transient loads	m	=	7.5	(Refer IRC : 22-2015, Cl.604.3)

Effective widh of flange for End Longitudinal Girder (Straight Span)	=	2.25 m	

3 Summary of forces (From MIDAS) -Factored Loads as per IRC 6:2017

AS PER IRC 6:2017, TABLE B.2, PAGE NO 93, THE LOAD FACTORS IS AS UNDER

Sl Nos	Load	Load Factor
1)	SW	1.35
2)	SIDL (W/O WC)	1.35
3)	WC	1.75
4)	VLL & FPLL	1.50



1) Check For Adequacy

STAGE 1: Laterally supported for the loadings of self weight of the girder with additional wt +Self wt of slabs + construction live load.

Calculation of Forces (Mid Span)

Total BM=			**23514.80**	**kNm**
Facored BM =	**1.35 x 23,514.80**		**31745.0**	**kNm**
SF due to self weight of the girder =		=	944.90	kN
SF due to Additional Wt =			141.74	kN
(15% of Weight of girder due to Stiffners, covers, bolts, etc)				
SF due to Deck Slab concrete =				
		=	1160.60	kN
SF Due to Construction live load				
SF=	1x 2.25x	51.3/2	57.71	kN
Total SF=			**2304.95**	**kNm**
Facored SF =	**1.35x2,304.95**		**3111.7**	**kNm**

Check for Shear (cl. 509.4, IRC:24-2010)

h	=	2510	mm
t_w	=	28	mm
t_f	=	45	mm
$d=h-2t_f$	=	2420	mm
b	=	850	mm
Av=	d*tw=	67760	mm2(For Welded connections) as per cl.509.4.1.1

As per cl 509.4, External Shear Force(V)<Vd

V_d= Design Shear Strength = V_n/γ_{mo}

$V_n=V_p=$ $A_v.f_{yw}/\sqrt{3}$

A_v=	67760	mm2
f_{yw}=	350	N/mm2
V_n=	**13692.4**	kN
γ_{mo}(From table-1,cl 503.4)	1.1	Resistance governed by yielding
	1.1	Resistance governed by buckling
	1.25	Resistance governed by ultimate stress

V_d= 12447.67 kN > 3111.68

Hence OK

Resistance to Shear Buckling (As per cl. 509.4.2)

Shear resistance to Web buckling shall be verified,

if, d/t_w $> 67\varepsilon$ for a web without stiffeners

$> 67\varepsilon \sqrt{(Kv/5.35)}$ for a web withstiffeners

Kv=Shear buckling coefficient =

Kv= 5.35 When transverse stiffners are provided only at supports

4+5.35/(c/d)^2 For c/d <1

5.35+4/(c/d)^2 For c/d ≥1

where, c= Spacing of transverse stiffeners= 1.50 m c/c

d= 2.42 m

c/d= 0.619834711 < 1

Kv= 17.925

ε = $\sqrt{250/fy}$ = 0.845

$67\varepsilon \sqrt{(Kv/5.35)}$ 103.649

d/t_w= 86.429

Verification of Shear Buckling Not Required

$V_n=V_{cr}$

Vcr= Shear Force corresponding to Web buckling

τ_{cre} = Elastic Critical Shear Stress of the Web

$\tau_{cre} = \frac{Kv\pi^2E}{12(1-\mu^2)(d/t_w)^2}$

τ_{cre} = 433.77 N/mm^2

Non Dimensional Web Slenderness ratio for shear buckling stress(λw)

$\lambda_w = \sqrt{f_{yw}/(\sqrt{3} * \tau_{cre})}$

λ_w= 1.25

Vcr= Av x τ_b

τ_b= $f_{yw}/\sqrt{3}$ if $\lambda_w \leq 0.8$

$(1-0.8(\lambda_w-0.8))*f_{yw}/\sqrt{3}$ if $0.8 < \lambda_w < 1.2$

$f_{yw}/(\sqrt{3}\lambda_w^2)$ if $\lambda_w \geq 1.2$

Hence, τ_b = 129.68 N/mm^2

V_{cr}= **8787.43** kN > **3111.68** kN

Hence OK

Check For Flexure- Check for Moment Resistance (cl. 509.2)

From cl. 503.7 and Table -2, IRC: 24-2010,

Check For Class of section

Width of Compression flange	B=	850 mm		
	b=	411 mm		
	t_f=	45 mm		
	d/t_w=	86.42857143		Section For Flange
	b/t_f=	9.13	<8.4ε	**SEMI COMPACT**
	d/t_w=	86.42857143	<126ε	**COMPACT**

Since the flange and web fall under different classes, section will be considered as **Semi compact**

Check for Flexure (Cl. 509.2.2,IRC:24-2010)

M_d= βb.Zp.fbd

where, β_b = 1.000 For Plastic and compact Section

Ze/Zp For Semi compact section = 0.856

f_{bd}= Design Bending Compressive stress (Tables 10a and 10b)

fbd = χ_{LT} fy / rmo

$\chi_{LT} = 1 / \{\phi_{LT} + [\phi_{LT}^2 - \lambda_{LT}^2]^{0.5}\}$

$\phi_{LT} = 0.5 \times (1 + \alpha LT (\lambda LT - 0.2) + \lambda LT2)$

α_{LT} = 0.21 (For Rolled Steel)

0.49 (For welded steel section)

λ_{LT}= vfy/fcr,b

$fcrb = 1.1 * \pi^2 * E / (L_{LT} / ry)^2 [1+1/20 [(L_{LT} / ry)/hf/Tf]^2]^{0.5}$

Centre to centre distance between bracings=	=	5690	mm
L_{LT} = 5690x1.2	=	6828	mm
r_y =	=	192.68	mm
h_f =	=	2465.0	mm
T_f =	=	45.00	
f_{crb}=	=	1746.97	N/mm^2
λ_{LT} =	=	0.448	

α_{LT} =	=	0.49	(For welded steel section)					
$\phi_{LT} = 0.5 \times (1+ \alpha LT (\lambda_{LT} - 0.2) + \lambda_{LT2})$	=	0.66						
$X_{LT} = 1 / \{\phi_{LT} + [\phi_{LT}^2 - \lambda_{LT}^2]^{0.5}\}$	=	0.872						
f_{bd}	=	277.40	N/mm^2					
M_d=	=	**33469.91**	**kNm**	>	**31744.98**	**kNm**	**OK**	

STAGE 2: Laterally supported for the loadings of self weight of the girder with additional wt +Self wt of slabs + SIDL + live load.

B) With composite action

a) End Longitudinal Girder (for mid span)

i) For dead load

Moment of inertia	Izz	=	2.26636E+11	mm^4
Section modulus from top	Ztop	=	178540975	mm^3
Section modulus from bottom	Zbot	=	147107279.3	mm^3
Area	A	=	190735.0	mm^2

i) For live load

Moment of inertia	Izz	=	2.71927E+11	mm^4
Section modulus from top	Ztop	=	2.56E+08	mm^3
Section modulus from bottom	Zbot	=	1.56E+08	mm^3
Area	A	=	232710.0	mm^2

2) Check For Moment of Resistance (As per Annexure-1, I.1.1)

Af= Area of Top flange of steel beam of a composite section=
As= Cross sectional area of Steel Beam of a composite section=
b_{eff}= Effective width of concrete slab
bf= Width of Top flange steel section
ds= Overall depth of the concrete slab
dc= Vertical distance between centroids of concrete slabs and steel beam in a composite section.
tf= Average thickness of top flange of the steel section=
tw= Thickness of Web of steel section
Xu= Depth of neutral axis at ultimate limit state of flexure from top of concrete
Mu= Ultimate Bending moment
γ_m= Material Safety factor for structural steel=

ds (Overall depth of concrete slab) is calculated to include the depth of concrete slab as well as the depth of haunch = For External girder = 249.85

Internal girder = 250.5

General data						
		External Girder		Internal Girder		
At Section from		End	Mid Span	End	Mid Span	m
Af		38250	38250	38250	38250	mm^2
As		148760.0	148760.0	148760.0	148760.0	mm^2
b_{eff}		2.57	2.57	2.50	2.50	m
bf		850	850	850	850	mm
d_s		0.250	0.250	0.251	0.251	m
d_c		1.48	1.48	1.48	1.48	m
t_f		45	45	45	45	mm
t_w		28	28	28	28	mm

γ_m		1.1	1.1	1.1	1.1
η		1.0	1.0	1.0	1.0
λ		0.8	0.8	0.8	0.8

Position of the Plastic neutral axis-

Case-1 : When neutral Axis is within the concrete slab

$x_u = \alpha$ As /beff

$\alpha = \frac{fy/\gamma m}{0.36\ f_{ck}} = 25.25$

Case-2 : When neutral Axis is in steel flange

$x_u = d_s + [\alpha As - b_{eff}\, d_s]/2bf\ \alpha$

Case-3: When neutral Axis is in web

$x_u = d_s + t_f + [a(As - 2A_f) - b_{eff} d_s]/2\alpha t_w$

		External Girder		**Internal Girder**		
At Section from		**End**	**Mid Span**	**End**	**Mid Span**	
For Case-2	x_u	322.43	322.43	323.42	323.42	mm
		Satisfied	Satisfied	Satisfied	Satisfied	

From above Cases, Neutral axis depth falls in web

Ultimate Moment of Resistance = Mp Case 1 = $A_s\ fy\ (d_c + 0.5\ d_s - \lambda\ x_u / 2)/\gamma_m$

Ultimate Moment of Resistance = Mp Case 2 = $fy[A_s\{d_c+0.5d_s(1 - \lambda)\} - b_f(x_u - d_s - t_f)\{x_u+(1-l)d_s\}]/\gamma_m$

Ultimate Moment of Resistance = Mp Case 3 = $f_y((A_s(d_c+0.1d_s) - 2A_f(0.5t_f+0.6d_s) - t_w(x_u - ds - t_f)(x_u+0.2d_s+t_f))/\gamma_m$

		External Girder		**Internal Girder**		
At Section from		**End**	**Mid Span**	**End**	**Mid Span**	m
Mp for Case 2		62843.24	62843.24	62932.98	62932.98	
Total Mp		**62843.24**	**62843.24**	**62932.98**	**62932.98**	kNm
Moment due to External Loads (Factored for DL) M_R		5051.87	10289.52	4507.39	9416.75	kNm
Check	**$M_p > M_R$**	**Hence Safe**	**Hence Safe**	**Hence Safe**	**Hence Safe**	

Check for Shear (cl.603.3.3.2, IRC:22-2015)

V ≤ Vd

V = The Factored Design Shear Force due external loads

Vd = The Design Shear Strength = Vn/Υ_{m0}

V_n = Nominal Plastic Shear Resistence = $Av.f_{yw}/\sqrt{3}$

Av = Shear Area without curtailment = d x t_w = 67760 mm^2 (For Welded connections) as per cl.509.4.1.1

Shear Area with curtailment = 67760 mm^2

Υ_{m0} = 1.10

f_{yw} = 350 N/mm^2

		External Girder		Internal Girder		
At Section from		**End**	**Mid Span**	**End**	**Mid Span**	
V		980.48	250.11	1057.87	282.40	kN
Av		67760	67760	67760	67760	mm^2
V_n		13692.44	13692.44	13692.44	13692.44	kN
Vd		12447.67	12447.67	12447.67	12447.67	kN
Check	**V≤ Vd**	**Safe**	**Safe**	**Safe**	**Safe**	

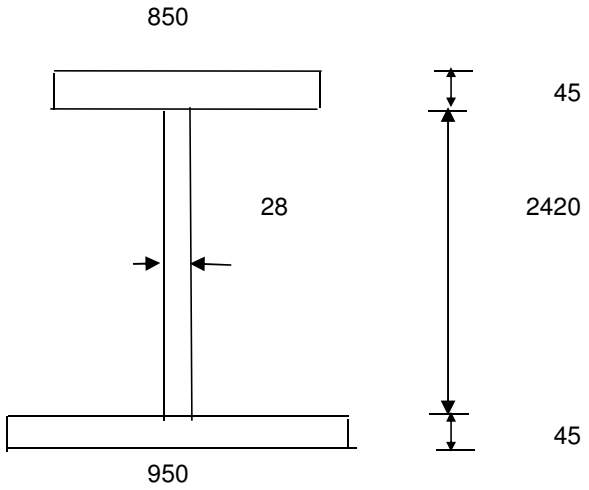
Check for Reduction of Bending resistance under high shear resistance

As per cl. 603.5.3.3, if V>0.6Vd, bending moment resistance is reduced

		External Girder		Internal Girder		
Distance from		**End**	**Mid Span**	**End**	**Mid Span**	m
Vd		12447.67	12447.67	12447.67	12447.67	kN
0.6 Vd		7468.60	7468.60	7468.60	7468.60	kN
Check	**V < 0.6V_d**	**OK**	**OK**	**OK**	**OK**	

Stress Check

Stage :1 Self weight of girder + Additional Weight



		At External Girder	At Internal Girder	
Area of girder	=	0.14876	0.14876	m2
Ztop	=	1.21E+08	120654343	mm3
Zbot	=	1.28E+08	128042565	mm3
Steel density	=	78.5	78.5	kN/m^{-3}
Effective Span	=	51.3	51.3	m
Yield Stress of steel	=	350	350	N/mm2
Deck Slab thickness	=	0.263	0.263	m
External Girder Distance	=	2.25	2.25	m

Concrete Density	=	25	25	kN/m^3	
Self weight of girder	=	11.68	11.68	kN/m	
Additional weight	=	1.75	1.75	kN/m	
Total	**=**	**13.43**	**13.43**	**kN/m**	
Bending moment at Mid Span	=	4417.72	4417.72	kN-m	
Shear Force at Support	=	344.46	344.46	kN	
Stress at top = M/Ztop	=	36.61	36.61	N/mm2	HENCE OK
Stress at bot = M/Zbot	=	34.50	34.50	N/mm2	HENCE OK
Shear Stress Tv	=	5.08	5.08	N/mm2	HENCE OK

Stage :2 Self weight of girder + Slab + Construction LL

		At External Girder	At Internal Girder		
Deck Slab Load	=	14.79	14.79	kN/m	
Haunch Load	=	1.78	1.78	kN/m	
Total	**=**	**16.58**	**16.58**	**kN/m**	
Bending moment at Mid Span	=	5452.5	5452.5	kN-m	
Shear Force at Support	=	425.1	425.1	kN	
Stress at top = M/Ztop	=	45.2	45.2	N/mm2	HENCE OK
Stress at bot = M/Zbot	=	42.6	42.6	N/mm2	HENCE OK
Shear Stress Tv	=	6.3	6.3	N/mm2	HENCE OK

Stage :3

Self weight of girder + Slab + Construction LL +SIDL+LL (COMPOSITE ACTION)+TEMPERATURE&SHRINKAGE

		At External Girder	At Internal Girder	
Ztop For DL	=	1.79E+08	1.77E+08	mm3
Ztop for top Flange DL	=	2.34E+08	2.31E+08	mm3
Zbot For DL	=	1.47E+08	1.47E+08	mm3
Ztop For VLL	=	2.56E+08	2.52E+08	mm3
Ztop for top Flange VLL	=	3.56E+08	3.50E+08	mm3
Zbot For VLL	=	1.56E+08	1.55E+08	mm3

	At External Girder	
	BM at mid span (kN-m)	SF at Support (kN)
SIDL	1046.9	186.6
WC	1697.1	215.7
FPDL	0	0
FPLL	0	0
VLL	4984.5	694.7
TotaL	**7728.5**	**1097**

Stress at top = M/Ztop	=	25.72	5.78	N/mm2	HENCE OK
Stress at bot = M/Zbot	=	50.68	11.77	N/mm2	HENCE OK
Stress at top(Temp)	=	1.67	1.67	N/mm2	HENCE OK
Stress at bottom(Temp)	=	0.04	0.04	N/mm2	HENCE OK
Stress at Top (Shrinkage)	=	5.75	5.82	N/mm2	HENCE OK
Stress at Bottom (Shrinkage)	=	9.14	9.16	N/mm2	HENCE OK
Shear Stress Tv	=	16.19	7.06	N/mm2	HENCE OK

Final Stress

(As per IRC24-2010 ,Table G.2)

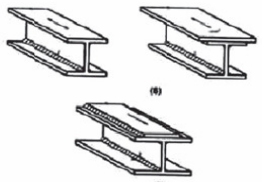
Permissible Stresses in Steel in Bending	=	0.62 * fy			
Tension	=	217.00		N/mm2	
Permissible Shear Stress	=	0.43 * fy			
	=	150.50		N/mm2	
Permissible Stresses in Concrete	=	0.48 * fck			
	=	19.2		MPa	
Actual Stress at top Flange	=	37+46+26+2+6	37+46+6+2+6		
	=	114.95	95.08	N/mm2	
					HENCE OK
Actual Stress at top Slab	=	3.62	3.67	N/mm2	
					HENCE OK
Actual Stress at bottom Flange	=	35+43+51+1+10	35+43+12+1+10		
	=	133.551	98.05	N/mm2	
					HENCE OK
Actual Shear Stress Tv	=	6+7+17	6+7+8		
	=	27.547	18.423	N/mm2	
					HENCE OK

Check for Fatigue

Maximum BM due to Fatigue Vehicle	=	2390.2	kNm
Stress at top = M/Ztop	=	**9.34**	MPa
Stress at bot = M/Zbot	=	**15.36**	MPa

Detail Category f_{fn} = 92 MPa

(Clauses **511.2.2.1** and **511.3**)

Sl No. (1)	Detail Category (2)	Constructional Details: Illustration (*see* Note) (3)	Constructional Details: Description (4)
i)	92		**Welded plate I-section and box girders with continuous longitudinal welds** (8) & (9) : Zones of continuous automatic longitudinal fillet or butt welds carried out from both sides and all welds not having un-repaired stop-start positions.

Number of Cycles / Year = 5.E+05 Cycles per year for bridge category 3
Service Life = 100 Years
Total Number of Cycles (Nsc) = 5.E+07 Cycles

When $5 \times 10^6 \le N_{SC} \le 10^8$ $f_f = f_{fn}\sqrt[5]{5x10^6 / N_{SC}}$

f_f = 58.05 MPa

γ_{mft} = 1.25

$\mu_r = (25/t_p)^{0.25} \le 1.0$

μ_r = 0.86

$f_{fd} = \mu_r f_f / \gamma_{mft}$

f_{fd} = 39.94 MPa

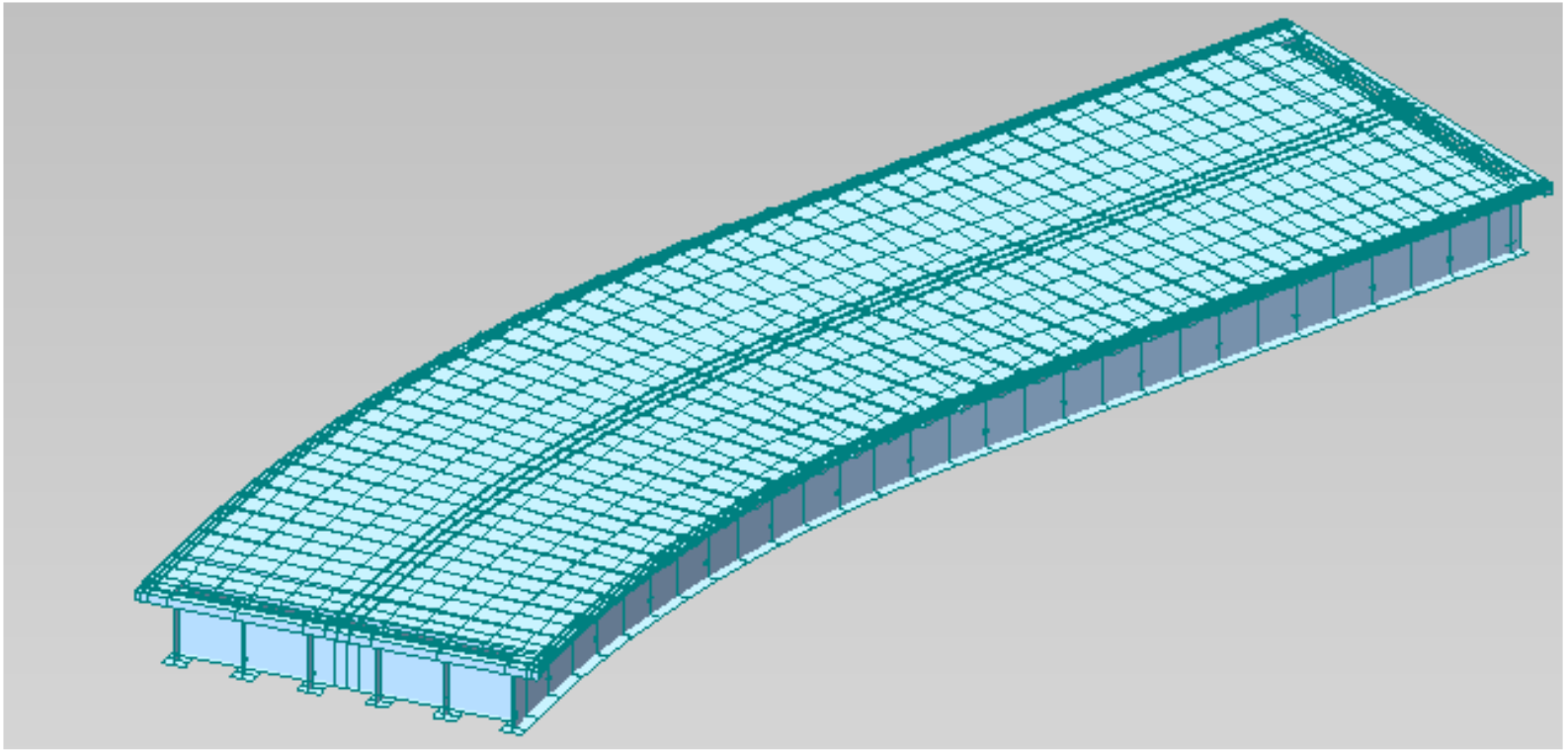
f_{fd}		f
39.94	**>**	**15.36**

Stress range is within fatigue limit, Hence OK

Preliminary Design of 60m Composite Steel Superstructure

Design of Composite Super Structure

General Design Data



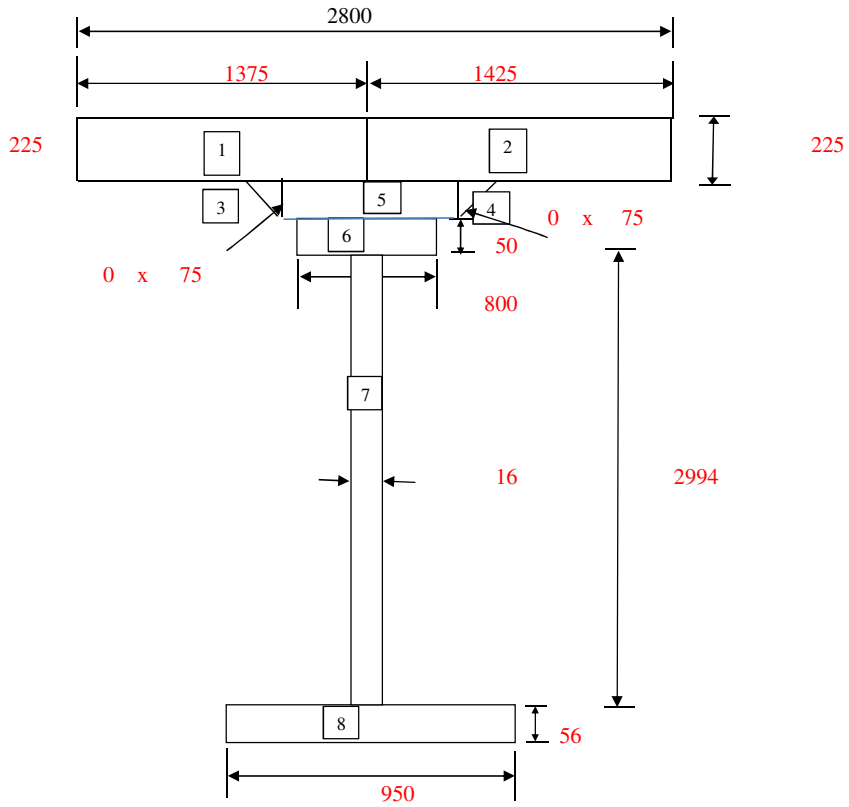
Effective span (C/C of bearing)	=	63.6	m	
Total Width of deck slab (Standard Span)	=	17	m	
Thickness of slab	=	0.263	m	(including average depth of concrete in decking sheet)
Width of carraigeway (Standard Span)	=	15	m	
C/C distance between girders (Standard Span)	=	2.85	m	
Maximum Yield stress of steel f_y	=	350	N/mm^2	(As per Table 2, IS: 2062-2011)

Grade of concrete	f_{ck}	=	40	N/mm^2	
Unit weight of concrete		=	25	kN/m^3	
Unit weight of steel		=	78.5	kN/m^3	
Modulus of Elasticity of concrete	Ecm	=	34000	N/mm^2	(As per Table- III.I, Anneure-I,IRC:22-2015)
Modulus of Elasticity of steel	Es	=	200000	N/mm^2	(As per IRC : 22-2015, Cl.604.3)
Modular ratio for permanent or long term loads	m	=	15		(As per IRC : 22-2015, Cl.604.3)
Modular ratio for transient loads	m	=	7.5		(As per IRC : 22-2015, Cl.604.3)
Spacing of the Cross Frame		=	4.250	m c/c	
Load due to wearing coat		=	2	kN/m^2	
Load due to crash barrier		=	8	kN/m	

The most critical girder (i.e. Outer Girder) is considered for the design

2a) CALCULATION OF SECTION PROPERTIES

1) END GIRDER



Haunch Width= 650

a) For Dead load

Modular ratio m = 15 (Refer IRC : 22-2015, Cl.604.3)

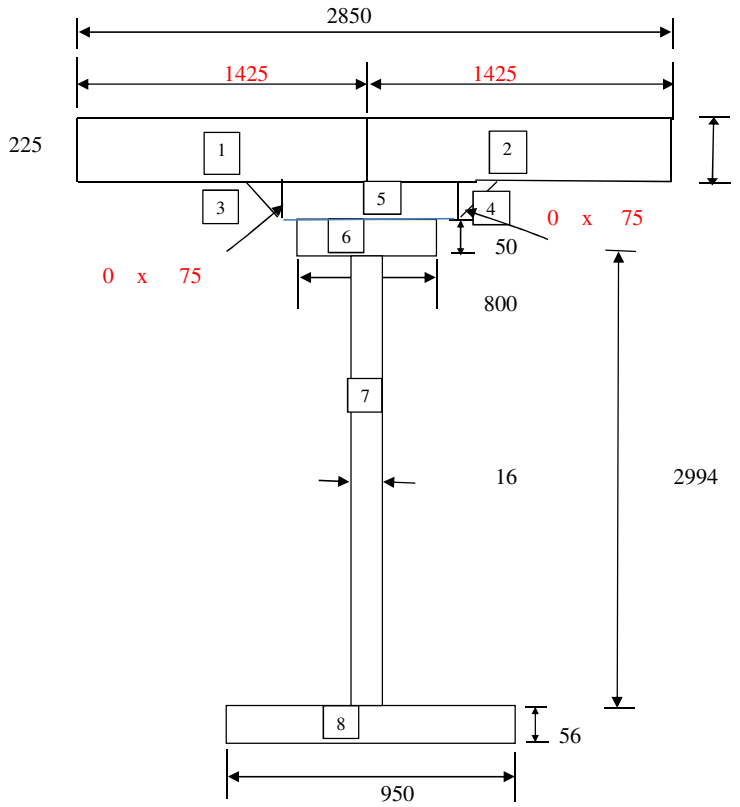
S No	Shape	B(mm)	D(mm)	Area	Y1 from top flange	AY	ybar	Iself	Aybar^2	Iz
1	Rectangle	91.67	225	20625.0	112.5	2320312.5	1424.6	87011719	41858913344	41945925063
2	Rectangle	95.00	225	21375.0	112.5	2404687.5	1424.6	90175781	43381055648	43471231429
3	Triangle	0	75	0.0	250.0	0.0	1287.1	0	0	0
4	Triangle	0.00	75	0.0	250.0	0.0	1287.1	0	0	0
5	Rectangle	43.33	75	3250.0	262.5	853125.0	1274.6	1523438	5280077008	5281600446
6	Rectangle	800	50	40000.0	325.0	13000000.0	1212.1	8333333	58768746650	58777079983
7	Rectangle	16	2994	47904.0	1847.0	88478688.0	-309.9	35784431712	4600209777	40384641489
8	Rectangle	950	56	53200.0	3372.0	179390400	-1834.9	13902933	179114248394	179128151327
				186354.0		**286447213**				**3.68989E+11**
	Ytop =	**1537.11**	mm		**Ztop =**	**240052980**	mm^3	**Ztop for top Flange =**	**298265832.2**	mm^3
	Ybot =	**1862.89**	mm		**Zbot =**	**198073576.3**	mm^3			

b) **For Vehicular Live load**

Modular ratio m = 7.5 (Refer IRC : 22-2015, Cl.604.3)

S No	Shape	B(mm)	D(mm)	Area	Y1 from top flange	AY	ybar	Iself	Aybar^2	Iz
1	Rectangle	183.33	225	41250.00	112.5	4640625	1148.38	174023437.50	54399734759	54573758197
2	Rectangle	190.00	225	42750.00	112.5	4809375	1148.38	180351562.50	56377906932	56558258495
3	Triangle	0.00	75	0.00	250.00	0	1010.88	0.00	0	0
4	Triangle	0.00	75	0.00	250.00	0	1010.88	0.00	0	0
5	Rectangle	86.67	75	6500.00	262.5	1706250	998.38	3046875.00	6478984321	6482031196
6	Rectangle	800	50	40000	325	13000000	935.88	8333333.33	35035012240	35043345573
7	Rectangle	16	2994	47904	1847	88478688	-586.12	3.5784E+10	16456661940	52241093652
8	Rectangle	950	56	53200	3372	179390400	-2111.12	13902933.33	2.37103E+11	2.37117E+11
				231604.00		**292025338**				**4.42015E+11**
	Ytop =	**1260.88**	mm		**Ztop =**	**3.51E+08**	mm^3	**Ztop for top Flange =**	**460009765.2**	mm^3
	Ybot =	**2139.12**	mm		**Zbot =**	**2.07E+08**	mm^3			

2) INTERNAL GIRDER



Haunch Width= 650

a) For Dead load

Modular ratio m = 15 (Refer IRC : 22-2015, Cl.604.3)

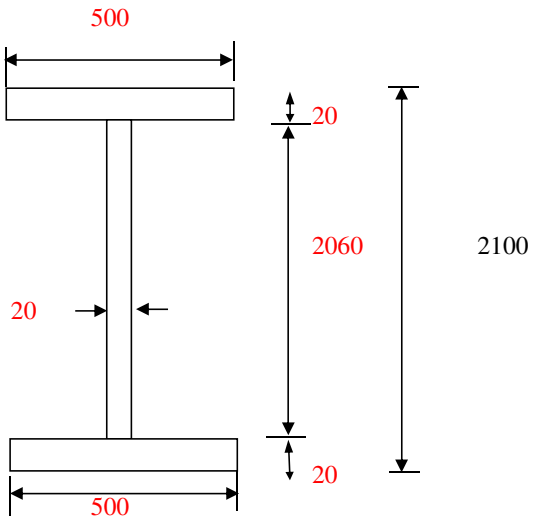
S No	Shape	B(mm)	D(mm)	Area	Y1 from top flange	AY	ybar	Iself	Aybar^2	Iz
1	Rectangle	95.00	225	21375.0	112.5	2404687.5	1418.9	90175781	43033969723	43124145504
2	Rectangle	95.00	225	21375.0	112.5	2404687.5	1418.9	90175781	43033969723	43124145504
3	Triangle	0	75	0.0	250.0	0.0	1281.4	0	0	0
4	Triangle	0	75	0.0	250.0	0.0	1281.4	0	0	0
5	Rectangle	43.33	75	3250.0	262.5	853125.0	1268.9	1523438	5232871461	5234394898
6	Rectangle	800	50	40000.0	325.0	13000000.0	1206.4	8333333	58216307865	58224641198
7	Rectangle	16	2994	47904.0	1847.0	88478688.0	-315.6	35784431712	4771314935	40555746647
8	Rectangle	950	56	53200.0	3372.0	179390400	-1840.6	13902933	180230857962	180244760895
				187104.0		**286531588**				**3.70508E+11**
	Ytop =	**1531.40**	mm		**Ztop =**	**241940158.8**	mm^3	**Ztop for top Flange =**	**300882730.7**	
	Ybot =	**1868.60**	mm		**Zbot =**	**198281273.8**	mm^3			

b) **For Vehicular Live load**

Modular ratio m = 7.5 (Refer IRC : 22-2015, Cl.604.3)

S No	Shape	B(mm)	D(mm)	Area	Y1 from top flange	AY	ybar	Iself	Aybar^2	Iz
1	Rectangle	190.00	225	42750.00	112.5	4809375	1140.99	180351562.50	55654669485	55835021048
2	Rectangle	190.00	225	42750.00	112.5	4809375	1140.99	180351562.50	55654669485	55835021048
3	Triangle	0.00	75	0.00	250.00	0	1003.49	0.00	0	0
4	Triangle	0.00	75	0.00	250.00	0	1003.49	0.00	0	0
5	Rectangle	86.67	75	6500.00	262.5	1706250	990.99	3046875.00	6383428346	6386475221
6	Rectangle	800	50	40000	325	13000000	928.49	8333333.33	34483924069	34492257403
7	Rectangle	16	2994	47904	1847	88478688	-593.51	3.5784E+10	16874245974	52658677686
8	Rectangle	950	56	53200	3372	179390400	-2118.51	13902933.33	2.38766E+11	2.38779E+11
				233104.00		**292194088**				**4.43987E+11**
	Ytop =	**1253.49**	mm		**Ztop =**	**3.54E+08**	mm^3	**Ztop for top Flange =**	**465642861.1**	
	Ybot =	**2146.51**	mm		**Zbot =**	**2.07E+08**	mm^3			

2b) PROPERTIES FOR END CROSS GIRDER



For Dead load

Modular ratio m = 15 (Refer IRC : 22-2015, Cl.604.3)

S No	Shape	B(mm)	D(mm)	Area	Y1	AY	ybar	Iself	Aybar^2	Iz
1	Rectangle	33.3333	0	0	0	0	1050	0	0	0
2	Rectangle	500	20	10000	10	100000	1040	333333.3	1.08E+10	10816333333
3	Rectangle	20	2060	41200	1050	43260000	0	14569693333.3	0	14569693333
4	Rectangle	500	20	10000	2090	20900000	-1040	333333.3	1.08E+10	10816333333
				61200		**64260000**				**36202360000**
	Ytop =	**1050**	mm		**Ztop =**	**34478438.1**	mm^3			

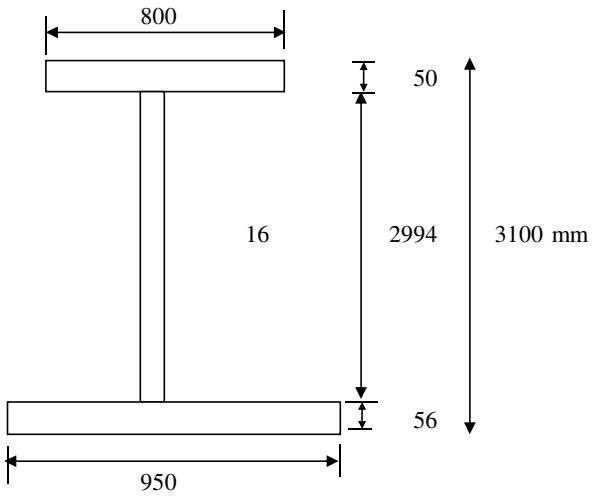
0.03620236

For Vehicular Live load

Modular ratio m = 7.5 (Refer IRC : 22-2015, Cl.604.3)

S No	Shape	B(mm)	D(mm)	Area	Y1	AY	ybar	Iself	Aybar^2	Iz
1	Rectangle	66.6667	0	0	0	0	1050	0	0	0
2	Rectangle	500	20	10000	10	100000	1040	333333.3	1.08E+10	10816333333
3	Rectangle	20	2060	41200	1050	43260000	0	14569693333	0	14569693333
4	Rectangle	500	20	10000	2090	20900000	-1040	333333.3	1.08E+10	10816333333
				61200		**64260000**				**36202360000**
	Ytop =	**1050**	mm		**Ztop =**	**34478438.1**	mm^3			

2c) PROPERTIES FOR GIRDER WITHOUT COMPOSITE



S No	Shape	B(mm)	D(mm)	Area	Y1	AY	ybar	Iself	Aybar^2	Iz	I_Y
1	Rectangle	800	50	40000	25	1000000	1665.51	8333333.333	1.10957E+11	1.10965E+11	2133333333
2	Rectangle	16	2994	47904	1547	74107488	143.51	35784431712	986604707.3	36771036419	1021952
3	Rectangle	950	56	53200	3072	163430400	-1381.49	13902933.33	1.01533E+11	1.01547E+11	4001083333
				141104		**238537888**				**2.49283E+11**	**6135438619**
	Ytop =	**1690.511**	mm		**Ztop =**	**147460236.5**	mm^3				
	Ybot =	**1409.489**	mm		**Zbot =**	**176860696.8**	mm^3				
						0.147460237			0.1411	0.0061	0.2493

3) DESIGN OF COMPOSITE GIRDER

1 Input

Effective span (C/C of bearing)	=	63.60	m
Total Width of deck slab	=	17	m
Thickness of slab	=	0.263	m
Width of carraigeway (Straight Span)	=	7.5	m
C/C distance between girders (Straight Span)	=	2.85	m

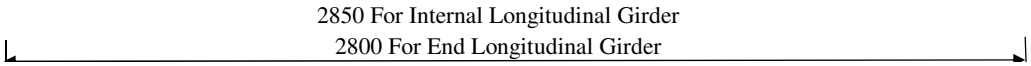
2 Material Properties

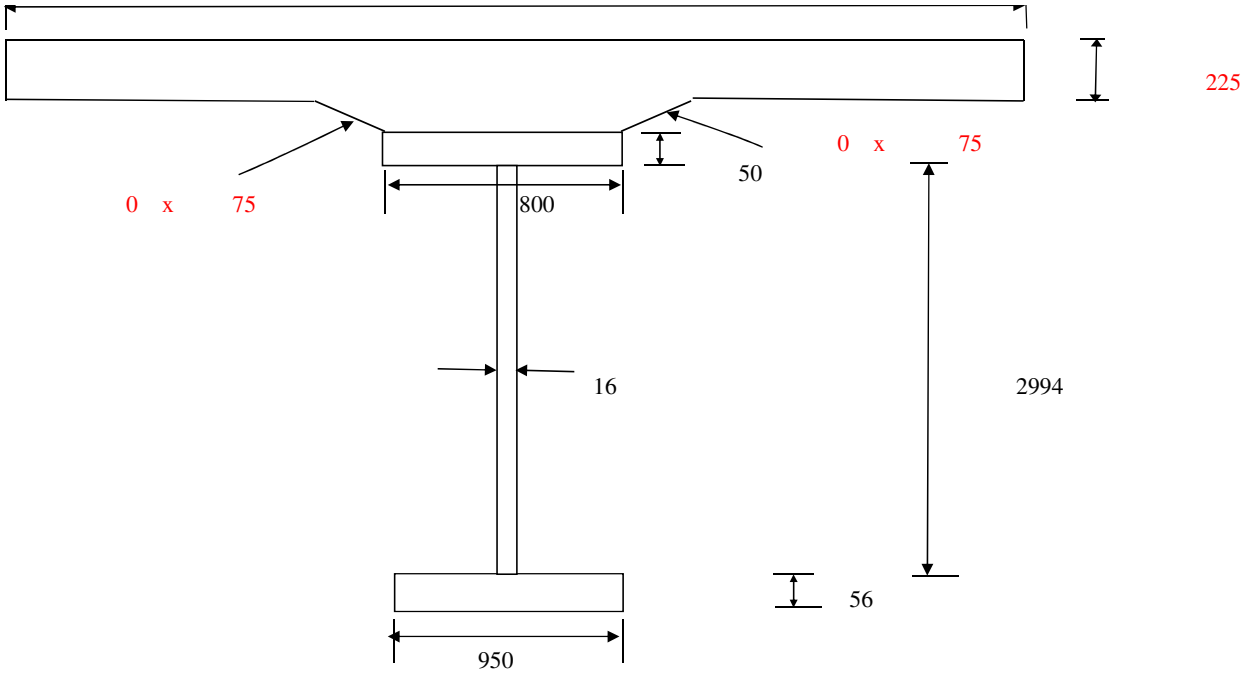
Yield stress of steel	f_y	=	350	N/mm^2	(As per Table 2, IS: 2062-2011)
Grade of concrete	f_{ck}	=	35	N/mm^2	
Unit weight of concrete		=	25	kN/m^3	
Unit weight of steel		=	78.5	kN/m^3	
Modulus of Elasticity of concrete	Ecm	=	33000	N/mm^2	(As per Table- III.I, Annexure-I,IRC:22-2015)
Modulus of Elasticity of steel	Es	=	200000	N/mm^2	(As per IRC : 22-2015, Cl.604.3)
Modular ratio for permanent or long term loads	m	=	15		(Refer IRC : 22-2015, Cl.604.3)
Modular ratio for transient loads	m	=	7.5		(Refer IRC : 22-2015, Cl.604.3)

3 Summary of forces (From Staad) -Factored Loads as per IRC 6:2017 (Refer Annexure ll for each load case details)

AS PER IRC 6:2017, TABLE B.2, PAGE NO 93, THE LOAD FACTORS IS AS UNDER

Sl Nos	Load	Load Factor
1)	SW	1.35
2)	SIDL (W/O WC)	1.35
3)	WC	1.75
4)	VLL & FPLL	1.50





1) Check For Adequacy

Properties and Data

Area	=	0.141104 m^2	
Y_{top}	=	1.691 m	
Y_{bot}	=	1.409 m	
I_z	=	0.249 m^4	
Z_{top}	=	0.147 m^3	
Z_{bot}	=	0.177 m^3	
Z_p	=	0.1750 m^3	
Unit Weight of steel =	=	78.50 kN/m^3	
Modulus of Elasticity (E_s)	=	2.0E+05 N/mm^2	
Poissons ratio	=	0.3	(As per Annexure-III,IRC:22-2015)
Yield Strength of Steel (F_{yw})	=	350 N/mm^2	(As per Table 2, IS: 2062-2011)

Unit Weight of Concrete	=	25	kN/m^3
Effective Span	=	63.6	m
Effective Span between Temporary Supports	=	50.59	m
Deck Width	=	17	m
Girder Spacing	=	2.25	m
Number of Girders	=	6	Nos
Cantilever projection	=	1.315	m
Deck Slab Thickness	=	0.263	m

STAGE-1 : Laterally supported for the loadings of self weight of the girder with additional wt +Self wt of slabs + construction live load.

Calculation of Forces (Mid Span)

Total BM= **30330.90 kNm**

Facored BM = **1.35 x 30,330.90** **40946.7 kNm**

SF due to self weight of the girder = = 944.90 kN

SF due to Additional Wt = 141.74 kN

(15% of Weight of girder due to Stiffners, covers, bolts, etc)

SF due to Deck Slab concrete = (0.263 x 25 x 2.25 x 63.6 / 2) + (0.125 x 25 x 63.6 / 2)

= 935.10 kN

SF Due to Construction live load

SF= 1x 2.25x 63.6/2 71.55 kN

Total SF= **2093.29 kNm**

Facored SF = **1.35x2,093.29** **2825.9 kNm**

Check for Shear (cl. 509.4, IRC:24-2010)

h	=	3100	mm
t_w	=	16	mm
t_f	=	50	mm
$d=h-2t_f$	=	2994	mm
b	=	800	mm

Av= d*tw= 47904 mm2(For Welded connections) as per cl.509.4.1.1

As per cl 509.4, External Shear Force(V)<Vd

V_d= Design Shear Strength = V_n/γ_{mo}

$V_n=V_p=$ $A_v.f_{yw}/\sqrt{3}$

$A_v=$ 47904 mm2

	f_{yw}=	350 N/mm2		
	V_n=	**9680.1** kN		
γ_{mo}(From table-1,cl 503.4)		1.1 Resistance governed by yielding		
		1.1 Resistance governed by buckling		
		1.25 Resistance governed by ultimate stress		
	V_d=	8800.08 kN	>	**2840.10** kN

Hence OK

Check For Flexure- **Check for Moment Resistance (cl. 509.2)**

From cl. 503.7 and Table -2, IRC: 24-2010,

Check For Class of section

Width of Compression flange	B=	800 mm		
	b=	392 mm		
	t_f=	50 mm		
	d/t_w=	187.125		Section For Flange
	b/t_f=	7.84	<8.4ε	**COMPACT**
	d/t_w=	187.125	<126ε	**SEMI COMPACT**

Since the flange and web fall under different classes, section will be considered as **SEMI COMPACT**

Check for Flexure (Cl. 509.2.2,IRC:24-2010)

M_d= βb.Zp.fbd

where, β_b = 1.000 For Plastic and compact Section

Ze/Zp For Semi compact section = 0.843

f_{bd}= Design Bending Compressive stress (Tables 10a and 10b)

fbd = χ_{LT} fy / rmo

$\chi_{LT} = 1 / \{\phi_{LT} + [\phi_{LT}^2 - \lambda_{LT}^2]^{0.5}\}$

$\phi_{LT} = 0.5 \times (1 + \alpha LT (\lambda LT - 0.2) + \lambda LT2)$

α_{LT} = 0.21 (For Rolled Steel)

0.49 (For welded steel section)

λ_{LT}= vfy/fcr,b

$fcrb = 1.1 * \pi^2 * E / (L_{LT} / ry)^2 [1+1/20 [(L_{LT} / ry)/hf/Tf]^2]^{0.5}$

Centre to centre distance between bracings=		=	4250	mm				
L_{LT} =	4250x1.2	=	5100	mm				
r_y	=	=	208.52	mm				
h_f	=	=	3047.0	mm				
T_f	=	=	50.00					
f_{crb}=	=	=	3644.44	N/mm^2				
λ_{LT}	=	=	0.310					
α_{LT}	=	=	0.49	(For welded steel section)				
$\phi_{LT} = 0.5 \times (1 + \alpha LT (\lambda_{LT} - 0.2) + \lambda_{LT2})$		=	0.57					
$X_{LT} = 1 / \{\phi_{LT} + [\phi_{LT}^2 - \lambda_{LT}^2]^{0.5}\}$		=	0.944					
f_{bd}		=	300.39	N/mm^2				
M_d=		=	**44295.99**	**kNm**	>	**40946.72**	**kNm**	**OK**

STAGE-2 : Laterally supported for the loadings of self weight of the girder with additional wt +Self wt of slabs + SIDL + live load.

B) With composite action

a) End Longitudinal Girder (for mid span)

i) For dead load

Moment of inertia	Izz	=	3.68989E+11	mm^4
Section modulus from top	Ztop	=	240052980	mm^3
Section modulus from bottom	Zbot	=	198073576.3	mm^3
Area	A	=	186354.0	mm^2

i) For live load

Moment of inertia	Izz	=	4.42015E+11	mm^4
Section modulus from top	Ztop	=	3.51E+08	mm^3
Section modulus from bottom	Zbot	=	2.07E+08	mm^3
Area	A	=	231604.0	mm^2

2) Check For Moment of Resistance (As per Annexure-1, I.1.1)

Af= Area of Top flange of steel beam of a composite section=
As= Cross sectional area of Steel Beam of a composite section=
b_{eff}= Effective width of concrete slab
bf= Width of Top flange steel section
ds= Overall depth of the concrete slab
dc= Vertical distance between centroids of concrete slabs and steel beam in a composite section.
tf= Average thickness of top flange of the steel section=
tw= Thickness of Web of steel section
Xu= Depth of neutral axis at ultimate limit state of flexure from top of concrete
Mu= Ultimate Bending moment
γ_m= Material Safety factor for structural steel=

ds (Overall depth of concrete slab) is calculated to include the depth of concrete slab as well as the depth of haunch = = 246.43

= 246.05

General data						
		External Girder		Internal Girder		
At Section from		End	mid span	End	mid span	m
Af		40000	40000	40000	40000	mm^2
As		128904.0	141104.0	128904.0	141104.0	mm^2
b_{eff}		2.80	2.80	2.85	2.85	m
bf		800	800	800	800	mm
d_s		0.246	0.246	0.246	0.246	m
d_c		1.88	1.88	1.88	1.88	m
t_f		50	50	50	50	mm
t_w		16	16	16	16	mm
γ_m		1.1	1.1	1.1	1.1	
η		1.0	1.0	1.0	1.0	
λ		0.8	0.8	0.8	0.8	

Position of the Plastic neutral axis-

Case-1 : When neutral Axis is within the concrete slab

$x_u = \alpha$ As /beff

$$\alpha = \frac{fy/\gamma m}{0.36\, f_{ck}} = 25.25$$

Case-2 : When neutral Axis is in steel flange

$x_u = d_s + [\alpha As - b_{eff}\, d_s]/2bf\, \alpha$

Case-3: When neutral Axis is in web

$x_u = d_s+t_f+[a(As-2A_f)-b_{eff}d_s]/2\alpha t_w$

			External Girder		Internal Girder	
At Section from		**End**	**mid span**	**End**	**mid span**	
For Case-2	x_u	309.92	317.54	309.26	316.88	mm
		Satisfied	Satisfied	Satisfied	Satisfied	

From above Cases, Neutral axis depth falls in web

Ultimate Moment of Resistance = Mp Case 1 = $A_s\ fy\ (d_c + 0.5\ d_s - \lambda\ x_u / 2)/\gamma_m$

Ultimate Moment of Resistance = Mp Case 2 = $fy[A_s\{d_c+0.5d_s(1 - \lambda)\}-b_f(x_u-d_s-t_f)\{x_u+(1-l)d_s\}]/\gamma_m$

Ultimate Moment of Resistance = Mp Case 3 = $f_y((A_s(d_c+0.1d_s)-2A_f(0.5t_f+0.6d_s)-t_w(x_u-ds-t_f)(x_u+0.2d_s+t_f))/\gamma_m$

			External Girder		Internal Girder	
At Section from		**End**	**mid span**	**End**	**mid span**	m
Mp for Case 2		73720.98	78523.19	73741.75	78504.67	
Total Mp		**73720.98**	**78523.19**	**73741.75**	**78504.67**	kNm
Moment due to External Loads (Factored for DL) M_R		5051.87	42217.00	4507.39	35015.40	kNm
Check	**$M_p > M_R$**	**Hence Safe**	**Hence Safe**	**Hence Safe**	**Hence Safe**	

Check for Shear (cl.603.3.3.2, IRC:22-2015)

V ≤ **Vd**

V = The Factored Design Shear Force due external loads

Vd = The Design Shear Strength = Vn/Υ_{m0}

V_n = Nominal Plastic Shear Resistence = $Av.f_{yw}/\sqrt{3}$

Av = Shear Area without curtailment = $d \times t_w$ = 47904 mm^2 (For Welded connections) as per cl.509.4.1.1

Shear Area with curtailment = 47904 mm^2

Υ_{m0} = 1.10

f_{yw} = 350 N/mm^2

			External Girder		Internal Girder	

At Section from		End	mid span	End	mid span	
V		3422.50	670.90	2686.40	368.30	kN
Av		47904	47904	47904	47904	mm^2
V_n		9680.09	9680.09	9680.09	9680.09	kN
Vd		8800.08	8800.08	8800.08	8800.08	kN
Check	**V≤ Vd**	**Safe**	**Safe**	**Safe**	**Safe**	

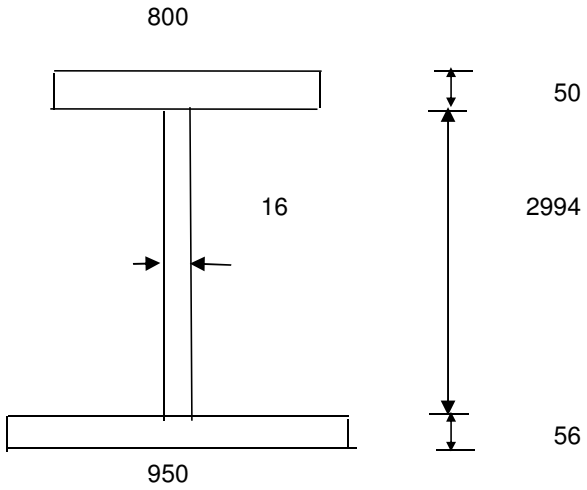
Check for Reduction of Bending resistance under high shear resistance

As per cl. 603.5.3.3, if V>0.6Vd, bending moment resistance is reduced

			External Girder		Internal Girder	
Distance from		**End**	**mid span**	**End**	**mid span**	m
Vd		8800.08	8800.08	8800.08	8800.08	kN
0.6 Vd		5280.05	5280.05	5280.05	5280.05	kN
Check	**$V < 0.6V_d$**	**OK**	**OK**	**OK**	**OK**	

Stress Check

Stage :1 Self weight of girder + Additional Weight



		At External Girder
Area of girder	=	0.141104
Ztop	=	1.47E+08
Zbot	=	1.77E+08
Steel density	=	78.5
Effective Span	=	63.6
Yield Stress of steel	=	350
Deck Slab thickness	=	0.263
External Girder Distance	=	2.25

Concrete Density	=	25	
Self weight of girder	=	11.08	
Additional weight	=	1.66	
Total	**=**	**12.74**	
Bending moment at Mid Span	=	13981.40	
Shear Force at Support	=	883.00	
Stress at top = M/Ztop	=	94.81	HENCE OK
Stress at bot = M/Zbot	=	79.05	HENCE OK
Shear Stress Tv	=	18.43	HENCE OK

Stage :2 Self weight of girder + Slab + Construction LL

		At External Girder	
Deck Slab Load	=	14.79	
Haunch Load	=	1.69	
Total	**=**	**16.48**	
Bending moment at Mid Span	=	30331.0	
Shear Force at Support	=	1987.7	
Stress at top = M/Ztop	=	205.7	HENCE OK
Stress at bot = M/Zbot	=	171.5	HENCE OK
Shear Stress Tv	=	41.5	HENCE OK

Stage :3

Self weight of girder + Slab + Construction LL +SIDL+LL (COMPOSITE ACTION)+TEMPERATURE&SHRINKAGE

		At External Girder	At Internal Girder	
Ztop For DL	=	2.40E+08	2.42E+08	mm3
Ztop for top Flange DL	=	2.98E+08	3.01E+08	mm3
Zbot For DL	=	1.98E+08	1.98E+08	mm3
Ztop For VLL	=	3.51E+08	3.54E+08	mm3
Ztop for top Flange VLL	=	4.60E+08	4.66E+08	mm3
Zbot For VLL	=	2.07E+08	2.07E+08	mm3

	At External Girder	
	BM at mid span (kN-m)	SF at Support (kN)
SIDL	1625.5	293.1
WC	3540	304.3
FPDL	0	0
FPLL	0	0
VLL	8730	686
TotaL	**13895.5**	**1283.4**

Stress at top = M/Ztop	=	36.30	4.37	N/mm2	HENCE OK
Stress at bot = M/Zbot	=	68.33	8.81	N/mm2	HENCE OK
Stress at top(Temp)	=	1.67	1.67	N/mm2	HENCE OK
Stress at bottom(Temp)	=	1.61	1.61	N/mm2	HENCE OK
Stress at Top (Shrinkage)	=	5.39	5.34	N/mm2	HENCE OK
Stress at Bottom (Shrinkage)	=	8.11	8.10	N/mm2	HENCE OK
Shear Stress Tv	=	26.79	9.99	N/mm2	HENCE OK

Final Stress

(As per IRC24-2010 ,Table G.2)

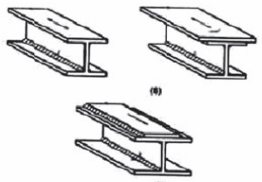
Permissible Stresses in Steel in Bending	=	0.62 * fy			
Tension	=	217.00		N/mm2	
Permissible Shear Stress	=	0.43 * fy			
	=	150.50		N/mm2	
Permissible Stresses in Concrete	=	0.48 * fck			
	=	19.2		MPa	
Actual Stress at top Flange	=	95+206+37+2+6	166+280+5+2+6		
	=	343.86	456.90	N/mm2	
					REVISE THE SECTION
Actual Stress at top Slab	=	4.75	4.71	N/mm2	
					HENCE OK
Actual Stress at bottom Flange	=	80+172+69+2+9	139+234+9+2+9		
	=	325.870	389.98	N/mm2	
					REVISE THE SECTION
Actual Shear Stress Tv	=	19+42+27	33+14+10		
	=	86.717	55.896	N/mm2	
					HENCE OK

Check for Fatigue

Maximum BM due to Fatigue Vehicle	=	4069	kNm
Stress at top = M/Ztop	=	**11.61**	MPa
Stress at bot = M/Zbot	=	**19.69**	MPa

Detail Category f_{fn} = 92 MPa

(Clauses **511.2.2.1** and **511.3**)

Sl No. (1)	Detail Category (2)	Constructional Details: Illustration (*see* Note) (3)	Constructional Details: Description (4)
i)	92		**Welded plate I-section and box girders with continuous longitudinal welds** (8) & (9) : Zones of continuous automatic longitudinal fillet or butt welds carried out from both sides and all welds not having un-repaired stop-start positions.

Number of Cycles / Year = 5.E+05 Cycles per year for bridge category 3

Service Life = 100 Years

Total Number of Cycles (Nsc) = 5.E+07 Cycles

When $5 \times 10^6 \le N_{SC} \le 10^8$ $\quad f_f = f_{fn}\sqrt[5]{5x10^6 / N_{SC}}$

f_f = 58.05 MPa

γ_{mft} = 1.25

$$\mu_r = (25/t_p)^{0.25} \le 1.0$$

μ_r = 0.82

$$f_{fd} = \mu_r f_f / \gamma_{mft}$$

f_{fd} = 38.08 MPa

f_{fd}		f
38.08	**>**	**19.69**

Stress range is within fatigue limit, Hence OK

Preliminary Design of Single pier with pile foundation supporting 8.5m deck.

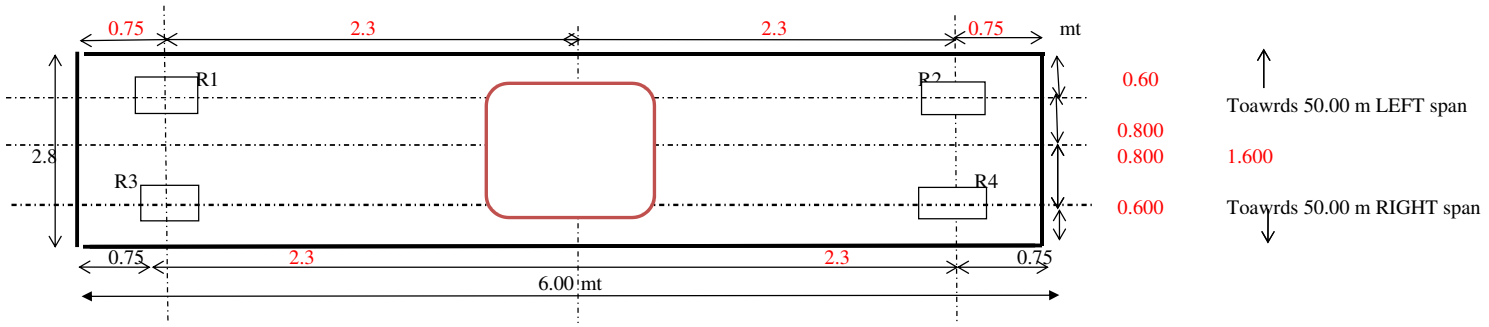
Design of Pier Substructure and Foundation for Piers between 50m and 50m Spans

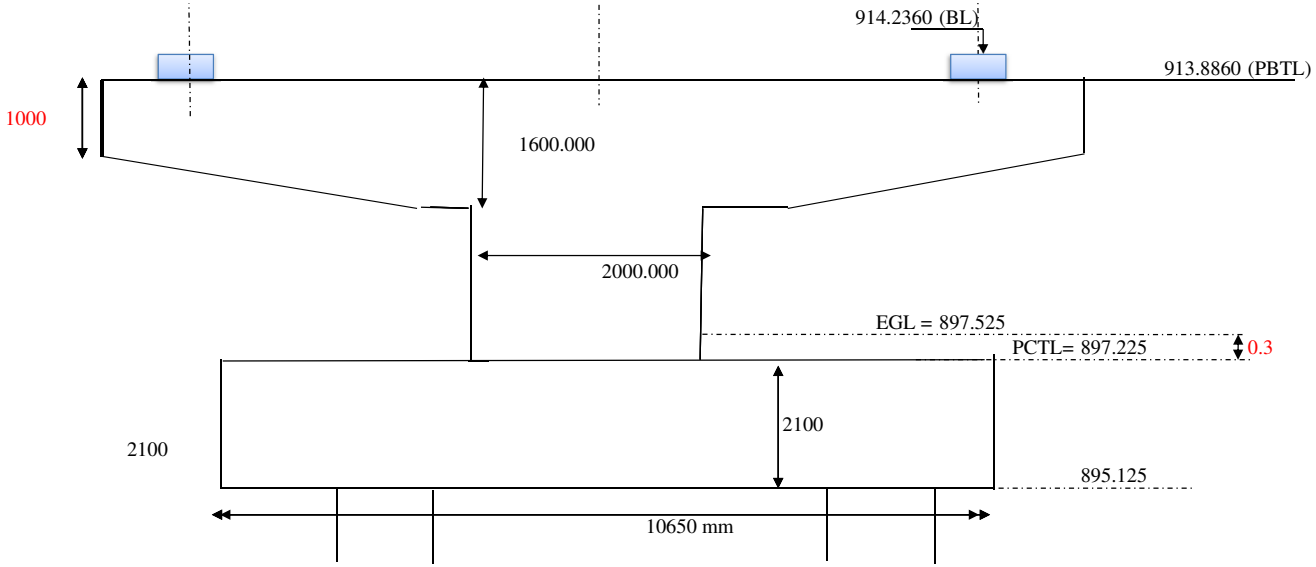
The Substructure is proposed with single Rectangular Pier with Pier Cap.The Foundation is Pile Foundation.The PTFE bearings are proposed on Pier Cap.
Pier Sustructure is analysed for load combinations as per IRC :IRC 6 and Designed following IRC 112-2011 codal provisions
This Design note presents design of Pier substructure and foundation for piers supporting 50m spans.

SCHEDULE OF LEVELS

Sl.No	PIER	FRL at edge of Median	EGL	Cross Slope	Superstructure depth +Wearing Coat	PBTL	PCTL	Total height of Pier (m)
1	P13	902.260	891.354	2.50%	2.764	899.1373	891.054	11.2060
2	P14	902.060	890.978	2.50%	2.764	898.9373	890.678	11.3820
3	P15	901.860	890.767	2.50%	2.764	898.7373	890.467	11.3930
4	P16	901.660	890.599	2.50%	2.764	898.5373	890.299	11.3610
6	P18	903.281	890.751	2.50%	2.764	900.1583	890.451	12.8300
7	P19	904.947	891.236	2.50%	2.764	901.8243	890.936	14.0110
8	P20	906.614	890.739	2.50%	2.764	903.4913	890.439	16.1750
9	P21	908.281	890.921	2.50%	2.764	905.1583	890.621	17.6600
10	P22	909.947	891.676	2.50%	2.764	906.8243	891.376	18.5710
11	P23	911.614	893.033	2.50%	2.764	908.4913	892.733	18.8810
12	P24	913.281	894.457	2.50%	2.764	910.1583	894.157	19.1240
13	P25	914.947	895.647	2.50%	2.764	911.8243	895.347	19.6000
14	P27	917.000	897.525	2.50%	2.764	913.8773	897.225	19.7750
15	P28	917.000	898.346	2.50%	2.764	913.8773	898.046	18.9540

Note: 1. From the above table, Pier P34 is critical, as the height of pier is more. Hence, design is carried out for P34, same details adopted for remaining piers in the group





1) GENERAL DATA FOR DESIGN

Finished Road Level	*FRL*	=	***917.000***	m	P26 Pier
Existing ground level	*EGL*	=	***897.525***	m	
Pier Bottom level	*PCTL*	=	***897.225***	m	
Pile Cap Bottom Level	*PCBL*	=	***895.125***	m	
Bearing Level	BL	=	***914.236***	m	
Height of super structure at centre of median (LEFT Span)	50.00 m span	SSD =	***2.712***	m	(Excluding wearing coat)
Height of Super Structure at centre of median (RIGHT Span)	50.00 m span	SSD =	***2.712***	m	(Excluding wearing coat)

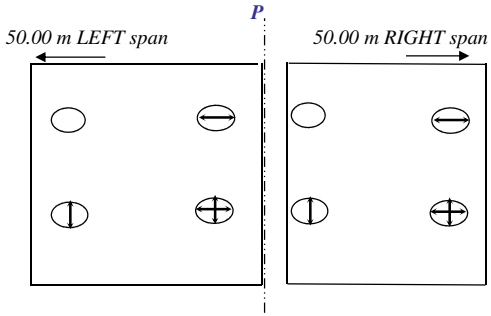
DATA FOR PIER DESIGN

Overall Span of the Bridge (Left Span)	*50.00 m span*	=	*50000*	*mm*	
Effective Span of the Bridge (Left Span)	*50.00 m span*	=	*48400*	*mm*	
Overall Span of the Bridge (Right Span)	*50.00 m span*	=	*50000*	*mm*	
Effective Span of the Bridge (Right Span)	*50.00 m span*	=	*48400*	*mm*	
Overall Width of Deck		=	*17000*	*mm*	
Width of Medain		=	*1000*	*mm*	
Overall Heigth of Substructure (From Bearing Level to Pile Cap Top Level)		=	***17011.000***	*mm*	
Width of pier at top (long)		=	2200	*mm*	
Length of pier at top (trans)			2000	*mm*	
Pier Cap Width in Long Dir^{n}.		=	***2800.000***	*mm*	
Pier Cap Length in Trans Dir^{n}.		=	***6000.000***	*mm*	
Straight Depth of Pier Cap		=	***1500.0***	*mm*	PTFE Bearing

Size of bearing for (LEFT Span)	50.00 m span	=	**900**	**x 900**	**x 150**	**2**	*Nos*
Size of bearing for (RIGHT Span)	50.00 m span	=	**900**	**x 900**	**x 150**	**2**	*Nos*
Size of Pedestals for (LEFT span)	50.00 m span	=	**1200**	**x 1200**	**x 200**	**2**	*Nos*
Size of Pedestals for (RIGHT span)	50.00 m span	=	**1200**	**x 1200**	**x 200**	**2**	*Nos*

Total straight Height of Pier (From Pier Cap bottom to Pier Bottom Level) = **15161** *mm* (*Max.Height*)

Width Of Pile Cap	=	**10650**	*mm*
Length of Pile Cap	=	**5850**	*mm*
Pile Cap Bottom Level	=	**895.125**	*m*
Thickness of Pile Cap	=	**2100**	*mm*
Thickness of Wearing coat	=	**52**	*mm*



Constants

Density of concrete	=	**25**	kN/m^3
Weight of wearing coat	=	**2**	kN/m^2
Grade of Concrete for Pier Cap,Pier	=	**M - 60**	*MPa.*
Grade of Concrete for Pile and Pile Cap	=	**M - 35**	*MPa.*
Grade of Steel (substructure)	=	**Fe - 550**	*MPa.*

AS PER IRC6:2016, TABLE B.2, PAGE NO 93, THE LOAD FACTORS IS AS UNDER

For Verification of Structural Strength

Sl Nos	*Loads*	*VLL is Leading & Wind is accompanying*	*Wind is Leading & VLL is accompanying*	*Seismic is Leading & VLL is accompanying*
1)	*SW =*	**1.35**	1.35	1.35
2)	*SIDL(W/o WC) =*	**1.35**	1.35	1.35
3)	*WC =*	**1.75**	1.75	1.75
4)	*VLL =*	**1.50**	1.15	0.2
5)	*BRAKING FORCE =*	**1.50**	*1.15*	0.2
6)	*WIND =*	**0.90**	*1.5*	-
7)	*Seismic =*	-	-	1.5

B.1) DEAD LOAD FROM SUPERSTRUCTURE(From STAAD)

Left Span 50,m ***Unfactored Loads***

	R1	*R2*
Self Weight	3338.00	3338.00
Crash Barrier+Median	282.20	282.20
WC	374.60	374.60
Total	***4069.72***	***4069.72***

Right Span- 50 m ***Unfactored Loads***

	R3	*R4*
DL	3333.00	3333.00
SIDL	282.20	282.20
WC	374.60	374.60
Total	***4064.72***	***4064.72***

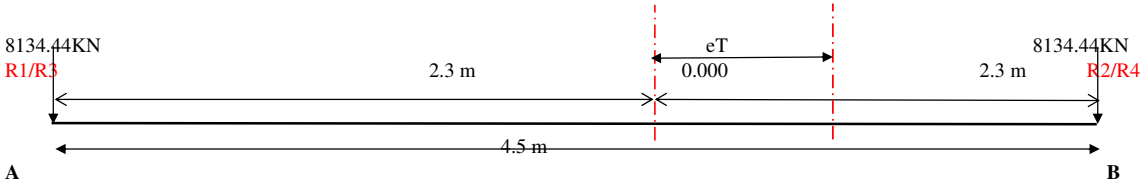
RESULTS FROM STAAD- 50.00 m LEFT span *Factored Loads*

	R1	R2
Self Weight	4506.30	4506.30
Crash Barrier+Median	380.97	380.97
WC	655.55	655.55
FPLL	0.00	0.00
TOTAL	**5542.82**	**5542.82**

RESULTS FROM STAAD- 50 m RIGHT span *Factored Loads*

	R3	R4
DL	4499.55	4499.55
SIDL	380.97	380.97
WC	655.55	655.55
FPLL	0.00	0.00
TOTAL	**5536.07**	**5536.07**

Cakculation of Transverse Moment due to Dead load



Cg of Loads from A	=		2.250	m
Cg of Loads from B	=		2.250	m
Eccentricity eT=	0.000	m		
MT=	0.00	KNm		(Unfactored)
MT=	0.00	KNm		(Factored)

Calcluation of Moment due to DL in Longitudinal Direction

50.00 e_L = 0.8 m

50.00 e_L = 0.800 m

Factored Longitudinal moment due dead load $M_{L\,(Factored)}$ = 8868.5 - 8857.71

= 10.8 kN-m

ML For Pier Cap Design=	5.40 (Factored)	ML For Pier Cap Design=	4.00 (Unfactored)
ML For Pier Design	10.80 (Factored)	ML For Pier Design	8.00 (Unfactored)

B.2) LIVE LOAD FROM SUPERSTRUCTURE

Following Vehicular Live loads are considered-

(i). 2 Class A vehicle

(ii). One 70RWL Vehicle

The variations of Live load combination is considered as per Table 2 of IRC 6-2017.

The reduction of longitudinal effect is considered as Cl:205 of IRC 6-2017

For 4 lanes Reduction in longitudinal effect = 20

Impact Factor : As per Cl 208 IRC : 6-2014
1) For Class A Vehicle,
2) For 70R Wheeled Vehicle

For 50.00m LEFT span	**L = 48.40 m**	For 50.00 m RIGHT span	**L = 48.40 m**
L= Effective Span	= 8.80% (Cl:208.2) = 8.80% (Cl:208.2)	IF=4.5/(6+L) L= Effective Span	= 8.80% (Cl:208.2) = 8.80% (Cl:208.2)

a) Vehicular Live Load from Staad pro.for 50.00 m LEFT Span (With impact Factor)

Eccentricity in longitudinal direction = 0.8 mt
For Four lanes 20 percent Reduction

Sl No	Vehicle case	R1(kN)	R2(kN)	R1(kN) Lane Reduction	R2(kN) Lane Reduction	Total reaction (kN)(Lane Reduction)	eL (mt)	ML (kNm)	eT (mt)	MT (kNm)
2	2CA+2CA	1113.80	1410.80	891.04	1128.64	**2019.68**	0.800	1615.74	0.265	534.60
4	70RWL+70RWL	949.50	1353.30	759.60	1082.64	**1842.24**	0.800	1473.79	0.395	726.84

b) Vehicular Live Load from Staad pro.for 50.00 m RIGHT Span (With impact Factor)

Summary of Reactions For Three Lanes: (From STADD Analysis)
For three lanes 20 percent Reduction
Eccentricity in longitudinal direction = 0.800 mt

Sl No	Vehicle case	R3(kN)	R4(kN)	R3(kN) Lane Reduction	R4(kN) Lane Reduction	Total reaction (kN)(Lane Reduction)	eL (mt)	ML (kNm)	eT (mt)	MT (kNm)
2	2CA+2CA	1113.80	1410.80	891.04	1128.64	**2019.68**	0.800	1615.74	0.265	534.60
4	70RWL+70RWL	949.50	1353.30	759.60	1082.64	**1842.24**	0.800	1473.79	0.395	726.84

c) Vehicular Live Load from Staad pro.for 50.00 m LEFT Span (Without impact Factor)

Eccentricity in longitudinal direction = 0.8 mt

Sl No	Vehicle case	R1(kN)	R2(kN)	R1(kN) Lane Reduction	R2(kN) Lane Reduction	Total reaction (kN)(Lane Reduction)	eL (mt)	ML (kNm)	eT (mt)	MT (kNm)
2	2CA+2CA	1015.79	1286.65	812.63	1029.32	**1841.95**	0.800	1473.56	0.26	487.56
4	70RWL+70RWL	865.94	1234.21	692.76	987.37	**1680.12**	0.800	1344.10	0.39	662.88

d) Vehicular Live Load from Staad pro.for 50.00 m LEFT Span (Without impact Factor)

Sl No	Vehicle case	R3(kN)	R4(kN)	R3(kN) Lane Reduction	R4(kN) Lane Reduction	Total reaction (kN)(Lane Reduction)	eL (mt)	ML (kNm)	eT (mt)	MT (kNm)
2	2CA+2CA	1015.79	1286.65	812.63	1029.32	**1841.95**	0.800	1473.56	0.26	487.56
4	70RWL+70RWL	865.94	1234.21	692.76	987.37	**1680.12**	0.800	1344.10	0.39	662.88

e) Vehicle on Both spans;

Summary of Reactions (From STADD Analysis)

Sl No	Vehicle case	R1(kN)	R2(kN)	R3(kN)	R4(kN)	R1(kN) Lane Reduction	R2(kN) Lane Reduction	R3(kN) Lane Reduction	R4(kN) Lane Reduction
2	2CA+2CA	626.00	352.10	604.50	340.00	500.80	281.68	483.60	272.00
4	70RWL+70RWL	689.50	253.70	659.50	242.70	551.60	202.96	527.60	194.16

Total reaction (kN)(Lane Reduction)	eL (mt)	ML (kNm)	eT (mt)	MT (kNm)
1538.08	0.800	21.50	0.63	969.12
1476.32	0.800	26.24	1.04	1534.68

f) Vehicle on Both span(Without impact Factor);

Sl No	Vehicle case	R1(kN)	R2(kN)	R3(kN)	R4(kN)	R1(kN) Lane Reduction	R2(kN) Lane Reduction	R3(kN) Lane Reduction	R4(kN) Lane Reduction
2	2CA+2CA	570.91	321.12	551.30	310.08	456.73	256.89	441.04	248.06
4	70RWL+70RWL	628.82	231.37	601.46	221.34	503.06	185.10	481.17	177.07

Total reaction (kN)(Lane Reduction)	eL (mt)	ML (kNm)	eT (mt)	MT (kNm)
1402.73	0.800	1122.18	0.63	883.84
1346.40	0.800	1077.12	1.04	1399.63

B.3 Braking Force (As per cl 211.2, IRC: 6- 2016)

Braking force is acts at 1.2 mt above road level

ML= HL x L.A

L.A = Lever Arm

Effective span (L) = 48.40 m

FRL = 917.000 m

1) For 50.00m LEFT span

Wearing coat = 0.052 m

Depth of super structure= 2.712 m

L.A = 2.764 + 1.2 = 3.96 m

Sl No	Vehicle case	1st,2nd and 3rdLANE in kN	3rd LANE in kN	1st & 2nd LANE(20%) in kN	3rd LANE(5%) in kN	Total HL in kN	ML=HL x L.A in kNm
2	2CA+2CA	1108.000	1108.000	110.800	55.400	166.200	658.817
4	70RWL+70RWL	1000.000	1000.000	200.000	50.000	250.000	991.000

Add Axial load(kN)	Add Axial	HL (kN) per	HL (kN) per
13.612	6.806	83.100	41.55
20.475	10.238	125.000	62.50

2) For 50.00 m RIGHT span

Wearing coat = 0.052 m

Depth of super structure= 2.712 m

L.A = 2.764 + 1.2 = 3.96 m

Effective span (L) = 48.4 m

FRL = 917.000 m

Sl No	Vehicle case	1st & 2nd LANE in kN	3rd LANE in kN	1st & 2nd LANE(20%) in kN	3rd LANE(5%) in kN	Total HL in kN	ML=HL x L.A in kNm
2	2CA+2CA	1108	1108.00	110.80	55.40	166.20	658.82
4	70RWL+70RWL	1000	1000.00	200.00	50.00	250.00	991.00

Add Axial load(kN)	Add Axial	HL (kN) per	HL (kN) per
13.61	6.81	83.10	41.55
20.48	10.24	125.00	62.50

Speciman calculation:

Additional axial load at bearing level= 110.8x(2.764+1.2)/48.4 9.075 kN

B.4 Friction Force (Normal Case): As per Cl.211.5.1.1 IRC:6-2016

Fixed Bearings : Fh - μ (Rg + Rq) or (Fh/2) + μ (Rg + Rq)

Fh = Applied Horizontal Force Due to Braking Effect

μ = Co-efficent Friction 0.05 For Surface between PTFE and Steel

Rg = Reaction @ Free End due to Dead load

Rq = Reaction @ Free End due to Live load

Free Bearings : μ(Rg+Rq)

μ = Co-efficent Friction 0.05

Rg = Reaction @ Free End due to Dead load

Rq = Reaction @ Free End due to Live load

For 50.00m LEFT span (one Span loaded case) (With impact Factor): Horizontal Force @ Bearing Level

Sl No	Vehicle case	Fh	μ	Rg / one side of span	Rq (one side of span)	μ (Rg + Rq) @ Free Bearing	μ (Rg + Rq) per Bearing	μ (Rg) per Bearing
2	2CA+2CA	0.00	0.05	8139.44	2019.68	507.96	253.9780	203.486
4	70RWL+70RWL	0.00	0.05	8139.44	1842.24	499.08	249.5420	203.486
						507.96		

For 50.00 m RIGHT span (one Span loaded case) (With impact Factor): Horizontal Force @ Bearing Level

Sl No	Vehicle case	Fh	μ	Rg	Rq	F_h+μ (Rg + Rq) @ Fixed Bearing	F_h+ μ (Rg + Rq) per Bearing
2	2CA+2CA	166.200	0.050	8139.440	2019.680	674.16	337.078
4	70RWL+70RWL	250.000	0.050	8139.440	1842.240	749.08	374.542

B.5. Centrifugal Force Due to Curvature effect (As per Cl.212.2),IRC:6-2016

The centrifugal Force shall be considered to act at a height of 1.2mt above road level

$C=W V^2/127R$

Where

R=Radius of curve= 310 mt

V=speed in kmph= 0.00 kmph

w=Total Vehicular Live Load in kN=

Centri Fugal Force is acts at 1.2 mt above road level

MT= HT x L.A effective span = R4(kN) mt

L.A = Lever Arm

FRL = 917.000

Wearing coat = 0.0520 mt
Depth of super structure= 2.712 mt
L.A = 2.764 + 1.2 = 3.964 mt

Sl No	Vehicle case	Tot. Vehi Live Load in kN	Centrifugal Force	Total HT in kN	MT=HT x L.A in kNm	Add Axial load(kN)	HT/Trestle (kN)
2	2CA+2CA	2216.000	0.00	0.00	0.00	0.00	0.00
4	70RWL+70RWL	2000.000	0.00	0.00	0.00	0.00	0.00

B.6 Wind load calculation as per IRC 6:2016 Cl:209

Wind Speed at the Project Site 33 m/s
Avg Ht of the deck above EGL 20.475 m (ht of superstr+1m Crash barrier)

Type of Terrain — Since the Grade separator is inside the city with well developed Buildings.

	Terrain with obstructions	
	Height	Pz
Upto	10	0.1905
	15	0.2305
	20	0.2650
	20.475 m	0.268

Pressure as per table 0.268 kN/sqm FRL 917.000
Pressure as per table, corresponds to basic wind speed of 33 m/s
Design wind pressure =(wind speed at site^2/33^2) x Wind pressure corresponding to 33 m/sec
Deisgn wind pressure = 0.2682775x(33^2/33^2= 0.268 kN/sqm
Design Pressure Pz= **0.268** kN/sqm GL 897.525
Wind Force in Transverse direction = Pz X A1 X G X Cd
G = gust factor = 2.00
Cd = drag coeff =
1.1 for Slab bridges with b/d>10
1.5 for Box/single beam b/d 2
1.3 for Box/single beam b/d> 6
2.25 for 2 or more Box/ beam b/d 2
1.95 for 2 or more Box/ beam b/d > 6
2.20 for single plate girder
2(1+c/20d) for multiple plate girders
C= Centre to centre distance of adjacent girders = 2.25 m d =

Cd = 1.3 Corresponding to Box Girder

Wind on Superstructure :

For 50.00m LEFT span			**For 50.00 m RIGHT span**		
Wind Force in Transverse direction = Pz X A1 X G X Cd			Wind Force in Transverse direction = Pz X A1 X G X Cd		
Length of span from Centre to centre of Expansion Joint =		50 m	Length of span from Centre to centre of Expansion Joint =		50 m
Effective Span =		48.4 m	Effective Span =		L = 48.40 m
Width of Deck =		17 m	Width of Deck =		17 m
Superstructure Depth		2.764 m	Superstructure Depth		2.764 m
Total depth =(Superstucture Depth + Crash barrier height (1m))	SSD= 2.764 m CBD= 1.00m	3.764 m	Total depth	SSD = 2.764 m CBD= 1.000 m	3.764 m
Area of Superstructure	3.764 x 50.000	**188.200**	Area of Superstructure =	3.764 x 50.000	**188.200**
Force in Transverse direction = Pz X A1 X G X Cd			Force in Transverse direction = Pz X A1 X G X Cd		
FT = 0.268x188.2x2x1.3		**131.27** m^2	FT = 0.268x50x2x1.3		**131.27** m^2

MT Bearing Level due to 50.00 m span

L.A = 3.764 /2 = 1.882 m

MT Bearing Level due to 50.00 m span **= 247 KNm**

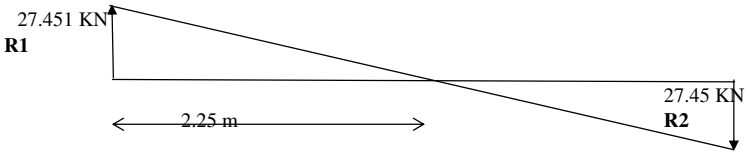
MT Bearing Level / span **= 124 KNm**

Add^{n} axial load = MT/(Eff.Bearing Spacing **123.53/4.5** **27.451** kN

Horizontal Force @ Bearing level per span = **65.637** kN

Force in long dir^{n} = 0.25 times FT = **32.818** kN

Add^{n} axial load = **32.82/48.4** = **1.3** kN



MT Bearing Level due to 50.00 m span

L.A = 3.764 /2 = 1.882 m

MT Bearing Level due to 50.00 m span **= 247 KNm**

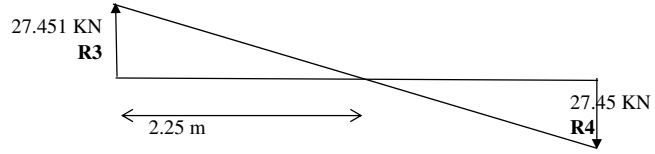
MT Bearing Level / span **= 124 KNm**

Add^{n} axial load = MT/(Eff.Bearing Spacing) = **123.53/4.5** **27.451** kN

Horizontal Force @ Bearing level per span= **65.637** kN

Force in long dir^{n} = 0.25 times FT = **32.818** kN

Add^{n} axial load = **32.82/48.4** = **1.28** kN



Wind Force on Vertical (+/-) **For 50.00 m span**

Fv = Pz X A3 X G X CL (As per IRC 6-2017,Cl:209.3.5)

A_3 = Area of Superstructure (plan area) 50.0 x 17.0

A_3 = **850.000** m^2

CL = lift coeff = 0.750 for Slab/ box/ I girders and plate girders

Fv = 0.268x850x2x0.75 = **= 342.1KN**

Fv/ one side = = **= 171.0KN**

Vertical Force per Bearing = $\frac{171.027}{2}$ = **= 85.5KN**

Wind Force on Vertical (+/-) **For 50.00 m span**

Fv = Pz X A3 X G X CL (As per IRC 6-2017,Cl:209.3.5)

A_3 = Superstructure (plan area) 50.0 x 17.0

A_3 = **850.0** m^2

CL = lift coeff = 0.750

Fv = 0.268x850x2x0.75 = **= 342.1KN** KN

Fv/ one side = **= 171.0KN**

cal Force per Bearing = $\frac{171.03}{2}$ = **= 85.5KN**

Wind on Live Load :

For 50.00m LEFT span

Force in Transverse direction = Pz X A1 X G X Cd

Ht of super structure +Crash Barrier = 3.764 m

Ht of vehicle considerded above Crash barrier= =3-1 2.0 m

Area of Superstructure 2 x 50.0 **= 100.0m2**

Cd = 1.2

L.A = 2.000 /2 + 3.764 = 4.764 m

FT = 0.268x100x2x1.2 = **64.39KN**

MT Bearing Level due to 50.00 m span **64.39KN**

L.A = 4.764 m

MT Bearing Level due to 50.00 m span

MT= 64.387 x 4.764 **= 307 KNm**

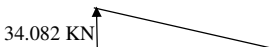
MT Bearing Level / span **= 153 KNm**

Add^{n} axial load = MT/(Eff.Bearing Spacing) = **153.37/4.5** **= 34.1KN**

Horizontal Force @ Bearing level per span = **= 32.2KN**

Force in long dir^{n} = 0.25 times FT **= 16.1KN**

Add^{n} axial load = **0.25x153.37/48.4** **= 0.8KN**



For 50.00 m RIGHT span

Force in Transverse direction = Pz X A1 X G X Cd

Ht of super structure +Crash Barrier = 3.76 m

Ht of vehicle considerded above Crash barrier= 2.0 m

rea of Superstructure A1 = 2 x 50.0 **= 100.0m2**

Cd = 1.2

L.A = 2.000 /2 + 3.764 = 4.764 m

FT = 0.268x100x2x1.2 = **64.39KN**

MT Bearing Level due to 50.00 m span

L.A = 4.764 m

MT Bearing Level due to 50.00 m span

MT= 64.387 x 4.764 **= 307 KNm**

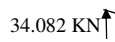
MT Bearing Level / span **= 153 KNm**

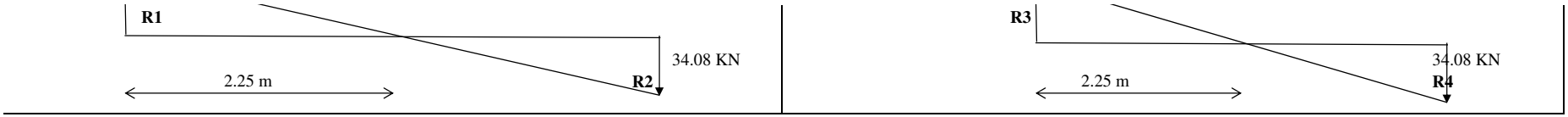
Add^{n} axial load = MT/(Eff.Bearing Spacing) = **153.37/4.5** **= 34.1KN**

Horizontal Force @ Bearing level per span = **= 32.19KN**

Force in long dir^{n} = 0.25 times FT **= 16.10KN**

Add^{n} axial load = **0.25x153.37/48.4** **= 0.79KN**





Summary of wind force at bearing level :

Sl No	Load case	HT (kN)	HT / Bearing (kN)	HL (kN)	HL / Bearing (kN)	Vertical Force(kN) / One side of span	Vertical Force(kN) / Bearing
1	Wind on loaded structure from 50.00m span (One side of LEFT span)	97.83	48.92	24.5	12.23	234.6	117.31
2	Wind on Unloaded structure from 50.00m span (One side of LEFT span)	65.64	32.82	16.4	8.20	199.8	99.88
3	Wind on loaded structure from 50.00m span (One side of RIGHT span)	97.83	48.915	24.5	12.229	234.6	117.314
4	Wind on Unloaded structure from 50.00m span (One side of RIGHT span)	65.64	32.818	16.4	8.205	199.8	99.877

DESIGN OF PIER CAP:

Distance from Face of Beam to cg of load — a = 1250.00 mm — No of Bearings on Cantilever Portion of Beam from LEFT — **50.00 m span** = 1

Thickness of corbel//Pier beam at face — h = 1600.000 mm

Effective depth of corbel/Pier beam — d' = 1492.000 mm — No of Bearings on Cantilever Portion of Beam from RIGHT — **50.00 m span** = 1

d = 1193.600 (0.8d')

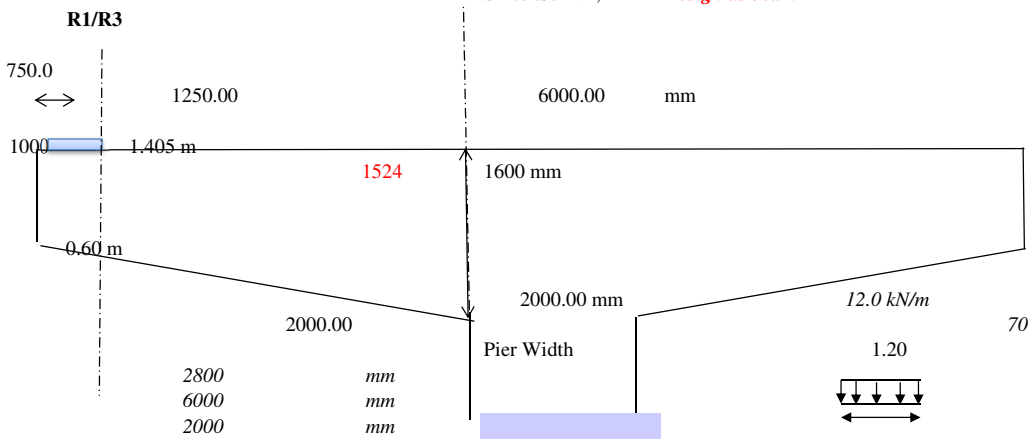
Thickness of Pier beam at end — S = 1000.000 mm

Eff. width of beam — b = 2800.000 mm

Checks

If a/d' <= 1.0 Design as a Corbel — actual a/d' = 0.838 — Vu/bd <= 0.15fc — 3.878 < 9.000 *safe*

Since a/d' < 1, ***Design as beam***



Lever Arms w.r.t face of pier	
L.A3=	1.250 m
L.A1=	1.250 m

Face of Pedestal-1

Pier Beam width =	2800	mm
Total length of Pier beam =	6000	mm
Pier Width =	2000	mm

Summary of Forces on Pier Cap (Pier Beam) **(TABLE No -1)**

1) Forces on Pier Cap due to Dead load

	Loads for Factored Combination	Loads for Rare combination	Loads for Frequent combination

Type of Loads		P (Shear) in kN	ML (Torsion) in kN-m	B.M (MT) in kN-m	P in kN	ML (Torsion) in kN-m	B.M (MT) in kN-m	P in kN	ML (Torsion) in kN-m	B.M (MT) in kN-m
Dead Load from Superstructure w.r.t to face of Pier	R1	5542.82	5.40	6928.53	4069.72	4.00	5087.15	4069.72	4.00	5087.15
	R3	5536.07	0.00	6920.09	4064.72	0.00	5080.90	4064.72	0.00	5080.90
Dead Load from superstructure w.r.t to face of Pedestal-@ (R1 +R5)	R1+R3	11078.89	5.40	6647.33	8134.44	4.00	4880.66	8134.44	4.00	4880.66

2) Forces on Pier Cap due to Vehicular Live load

Type of Loads		Loads for Factored Combination			Loads for Rare combination			Loads for Frequent combination		
		P (Shear) in kN	ML (Torsion) in kN-m	B.M (MT) in kN-m	P in kN	ML (Torsion) in kN-m	B.M (MT) in kN-m	P in kN	ML (Torsion) in kN-m	B.M (MT) in kN-m
VLL (One Span) w.r.t face of Pier	R1	1336.56	1069.25	*1670.70*	891.04	712.83	*1113.80*	668.28	534.62	*835.35*
	R3	1336.56	1069.25	*1670.70*	891.04	712.83	*1113.80*	668.28	534.62	*835.35*
VLL (One Span) w.r.t face of Pedestal@	R1	1336.56	1069.25	801.94	891.04	712.83	534.62	668.28	534.62	*400.97*
VLL (Both Span) w.r.t face of Pier	R1	1118.40	38.88	*1398.00*	745.60	25.92	*932.00*	559.20	19.44	*699.00*
	R3	1069.80	0.00	*1337.25*	713.20	0.00	*891.50*	534.90	0.00	*668.63*
VLL (Both Span) w.r.t face of Pedestal-(R1+R5)		2188.20	38.88	1312.92	745.60	25.92	447.36	559.20	19.44	335.52

3) Forces on Pier Cap due to Braking Force and Frictional Force

Type of Loads	Loads for Factored Combination			Loads for Rare combination			Loads for Frequent combination		
	P (Shear) in kN	ML (Torsion) in kN-m	B.M (MT) in kN-m	P in kN	ML (Torsion) in kN-m	B.M (MT) in kN-m	P in kN	ML (Torsion) in kN-m	B.M (MT) in kN-m
Braking and Frictional Force at Bearing level (LEFT From 33.4m span)									
Braking force w.r.t face of Pier (R1)	15.36	742.89	19.20	10.24	495.26	12.80	7.68	371.44	9.60
Braking force w.r.t face of Pedestal@ (R1)	15.36	668.60	9.21	10.24	445.73	12.80	7.68	334.30	9.60
Braking and Frictional Force at Bearing level (RIGHT From 33.4m span)									
Braking force w.r.t face of Pier (R3)	15.36	1095.54	19.20	10.24	730.36	12.80	7.68	547.77	9.60
Braking force w.r.t face of Pedestal@ (R3)	15.36	985.98	9.21	10.24	657.32	6.14	7.68	492.99	4.61

4) Force due to Self Weight of Pier Beam and Pedestal

Type of Loads	Loads for Factored Combination			Loads for Rare combination			Loads for Frequent combination		
	P (Shear) in kN	ML (Torsion) in kN-m	B.M (MT) in kN-m	P in kN	ML (Torsion) in kN-m	B.M (MT) in kN-m	P in kN	ML (Torsion) in kN-m	B.M (MT) in kN-m
Force due to Self Weight of Pier Beam									
Pier Beam w.r .t face of Pier	245.70		*226.76*	182.00		*167.97*	182.00		*182.00*
Pier Beam w.r .t face of Pedestal	153.41		*97.73*	113.64	0.00	*72.39*	113.64	0.00	*72.39*

Force due to Self Weight of Pedestal									
Pedestal w.r.t to face of Pier @ (R1+R3)	19.44		24.30	14.40	0.00	18.00	14.40	0.00	18.00
Pedestal w.r.t to face of Pedestal-@ (R1+R3)	19.44		11.66	14.40	0.00	8.64	14.40	0.00	8.64

5) Forces due to Wind on Pier Cap

Type of Loads	**Loads for Factored Combination**			**Loads for Rare combination**			**Loads for Frequent combination**		
	P (Shear) in kN	***ML (Torsion) in kN-m***	***B.M (MT) in kN-m***	***P in kN***	***ML (Torsion) in kN-m***	***B.M (MT) in kN-m***	***P in kN***	***ML (Torsion) in kN-m***	***B.M (MT) in kN-m***
Wind Forces on Super structure									
Wind on Super Structure w.r.t face of Pier @ (R1+R3)	49.41	113.18	*452.74*	32.94	75.46	*301.82*	27.45	62.88	251.52
Wind on Super Structure w.r.t face of Pedestal-@ (R1+R3)	49.41	107.42	*429.70*	32.94	71.62	*286.47*	27.45	59.68	238.72
Wind Forces on Live Load									
Wind on Live Load w.r.t face of Pier @ (R1+R3)	61.35	97.27	*389.06*	40.90	64.84	259.37	34.08	54.04	216.15
Wind on Live Load w.r.t face of Pedestal-@ (R1+R3)	61.35	94.44	*377.76*	40.90	62.96	251.84	34.08	52.47	209.87
Vertical force due to Wind									
Verticle wind load per Bearing w.r.t face of Pier @ (R1+R3)	153.92	0.00	*192.41*	102.62	0.00	128.27	85.51	0.00	106.89
Verticle wind load per Bearing w.r.t face of Pedestal-@ (R1+R3)	153.92	0.00	92.35	102.62	0.00	61.57	85.51	0.00	51.31

Load Combinations:
Comb:-1 DL+VLL (Braking,Centrifugal,Frictional Force)+Wind Load (VLL One Span Condition)
Comb:-2 DL+VLL (Braking,Centrifugal,Frictional Force)+Wind Load (VLL Both Span Condition)

Summary of Forces **(TABLE No -2)** **(Combination 1)**

Load Combination	**Pier Cap Forces w.r.t face of Pier**			**Pier Cap Forces w.r.t face of Pedestal @ (R1+R5)**		
	P (Shear) in kN	***ML (Torsion) in kN-m***	***B.M in kN-m***	***P (Shear) in kN***	***ML (Torsion) in kN-m***	***B.M in kN-m***
Factored Combination	**12960.6**	**2380.63**	**16823.8**	**12868.3**	**2262.5**	**8467.7**
Rare Combination	**9408.57**	**1587.49**	**12170.09**	**9340.21**	**1508.73**	**6108.99**
Frequent Combination	**9153.84**	**1203.31**	**11787.56**	**9085.48**	**1143.76**	**5872.16**
Quasi Permanent Combination	**8330.84**	**4.00**	**10354.02**	**11251.74**	**5.40**	**6756.72**

Summary of Forces **(TABLE No -3)** **(Combination 2)**

Load Combination	**Pier Cap Forces w.r.t face of Pier**			**Pier Cap Forces w.r.t face of Pedestal @ (R1+R5)**		
	P (Shear) in kN	***ML (Torsion) in kN-m***	***B.M in kN-m***	***P (Shear) in kN***	***ML (Torsion) in kN-m***	***B.M in kN-m***
Factored Combination	**13812.3**	**2093.15**	**17888.3**	**13720.0**	**1900.7**	**8978.7**
Rare Combination	**9976.33**	**900.58**	**12879.79**	**9194.77**	**821.82**	**6021.73**
Frequent Combination	**9579.66**	**688.12**	**12319.83**	**8976.40**	**628.58**	**5806.71**

Quasi Permanent Combination	**8330.84**	**4.00**	**10354.02**	**8262.48**	**4.00**	**4961.69**

1) DESIGN OF PIER CAP

Grade of concrete = M60
Grade of steel = Fe550

Q = 0.133 fck (for Fe 500)
Q = 7.98 N/mm2

Design Moment = 17888.32 kNm (Combination 2) Table 3 — Clear Cover = **40** mm
Effective Depth Reqd "deff" = $\frac{M}{Q \times B}$ — Bar Dia = **32** mm

deff reqd: = $\sqrt{\frac{17888.32 \times 1000000}{7.98 \times 2800}}$

= **894.76** mm < **1524.00** mm **O.K**

deff provided = 1600 - 40 - 20.0 = **1524.00**

Area of steel required (Ast) = (50*fck/fy)*(1-sqrt(1-(4.5*Mu/(fck*b*d^2))))*b*d/100

∴ Ast reqd = 27163.30 mm^2

Ast reqd for launching Girder case = 26469.36 mm^2

As1 = 804.2 mm^2

No of bars Reqd: = $\frac{27163.3}{804.2}$ = 33.77 → **40** Nos

Spacing of Bars = $\frac{2800}{40}$ = 70.00 mm

So provide **32** mm dia bars , **70** mm c/c spacing in **2** **layer** of 20 Nos
Ast Provided 32169.9 mm^2

Compression reinforcement **25** mm dia bars , **of 20 Nos**

Check for Serviceability Limit State

1) Stress Check Calculation As per IRC 112-2011 (Quasi Permanent Combination-Table No B.3 of IRC6-2016)

Width of pier beam =	b=	2800
Thickness of Beam (mm)	h =	1600
Dia of main Bar (mm)		32
Effective Depth (deff) mm		1524
Ast pro (mm2)		32170
Max Moment (kN-m)		13250.61
Es (N/mm^2)		200000
Ecm (N/mm^2)		16017
m = α = Es/Ecm		12.49
X_U (mm) =		533.18
L.A (mm) =		1346.27
Stress in Steel (N/mm2)		305.95
Permissible stress in steel		440
Check for stree in steel		Hence OK
Stress in Concrete (N/mm2)		13.19
Permissible stress in concrete		22

(Ref Table No-2 and 3)

L.A= d - Xu/3

Stress in Steel = M/ (Ast xL.A)
Stress in concrete= M/ (0.5.Xu.b.(L.A)

$X_u^2/2$ =m Ast (d-X_u)

a 1400.00
b 401689.13
c -612174236
Xu 1 = 533.18
Xu 2= -820.11

Check for stree in concrete		**Hence OK**

2) Crack Width Calculation As per IRC 112-2011 (Quasi Permanent Combination-Table No B.3 of IRC6-2016)

(As per IRC 112-2011, Cl:12.3.4)

Dia of main Bar (mm)		32
Spacing of Bars (mm)		140
Max Moment (kN-m)		13250.61 (Ref Table No-2 and 3)
Ast pro As (mm^2)		32169.91
C_{min} (mm)		40
a_{cr} (mm)		73.64
h (mm)		1600.00
d (mm)		1524.00
Es (N/mm^2)		200000
Ecm (N/mm^2)		16017
m = α = Es/Ecm		12.49
Xu (mm)		533.18
s_{sc} (N/mm^2)		305.95
k_t =		0.5
$f_{ct,eff}$ (N/mm^2)		3.3
$A_{c,eff} = b*h_{c,eff}$ (mm^2)		532000.00
$h_{c,eff}$ least of	2.5 (h - d)	190.0
	(h - Xu/3)	1422.3
	h / 2	800.0
$r_{P,eff}$ =		0.0605
$e_{sm} - e_{cm}$ =		0.0013
		≥ 0.0009
$e_{sm} - e_{cm}$ =		0.0013
IRC 112-2011	k1 =	0.8
	k2 =	0.5
Spacing	5(c + F/2) =	280.00
Case(i)	$S_{r,max}$ (mm)=	225.96
Case(ii)	$S_{r,max}$ (mm) =	1386.86
$S_{r,max}$ (mm) =		225.96
W_k (mm) =		0.292
Check for Crack Width		***Hence OK***

3) Stress Check for Provided Steel (Rare Combination) (As per Table No B.3 of IRC6-2016)

Width of pier beam =		b=	2800
Thickness of Beam (mm)		h =	1600
Dia of main Bar (mm)			32
Effective Depth (deff) mm			1524
Ast pro (mm2)			32170
Max Moment (kN-m)			13250.61 (Combination 2) Table 3
Es (N/mm^2)			200000
Ecm (N/mm^2)			16017

L.A= d - Xu/3

Stress in Steel = M/ (Ast xL.A)

Stress in concrete= M/ (0.5.Xu.b.(L.A)

a 1400.00

b $X_u^2/2$ =m Ast ($d-X_u$) b 401689.13

m = α = Es/Ecm		12.49
X_U (mm) =		533.18
L.A (mm) =		1346.27
Stress in Steel (N/mm2)		305.95
Permissible stress in steel		479
Check for stree in steel		**Hence OK**
Stress in Concrete (N/mm2)		13.19
Permissible stress in concrete		29
Check for stree in concrete		**Hence OK**

c -612174236
Xu 1 = 533.18
Xu 2= -820.11

4) Deflection Check (By Freqent Combination-Table No B.3 of IRC6-2016)

For Cantiliver Slab *Deflection = $P*l^3$ / 3EI*

I = M.I = $bD^3/12$ = *9.55733E+11* mm2

Ec,eff = Ecm / (1+ ø)

Ecm = 37000 MPa (as per IRC-112, table-6.5) (Ref Table No-2 and 3)

P = 9579.66 *KN*

As per IRC:112-2011, table-6.9, for RH-80%, & 28 days age loading L = 1.25 *m*

ø 1= 1.7 for 150

ø 2= 1.5 for 600

ø = **1.31** for 1018 2Ac/u = 1018.18

Ec,eff = 16017.32

deflection = 0.41 mm

For cantiliver, as per IRC-112:2011, Cl:12.4.1(2)

δ = span / 300 4.17 *mm*

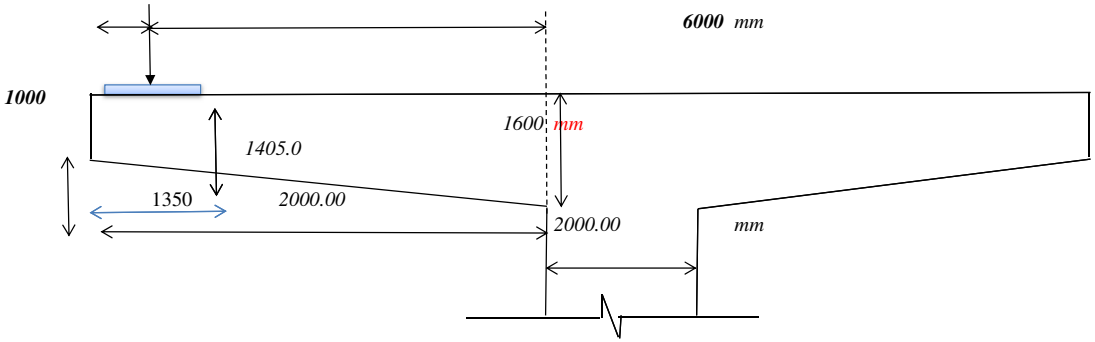
> *0.41* **Hence OK**

Check for Shear ***(As per Cl 10.3 of IRC 112-2011)***

pedestal size= 1.20 x 1.20 x 0.20 mt

R1/R3

750 *1250.0*



Check for Shear at the face of Pedestal @ (R1+R3)

Widh of Pier Cap (B) = 2800 mm

Depth at face of Pedestal (D)= 1405.0 mm

Effective depth at face of Pedestal (d)= 1297.0 mm

Total Shear force at face of Pedestal = *13720.0 KN* (Combination 2) Table 3

Moment at face of Pedestal (MT) = *8978.7 KNm* (Combination 2) Table 3

Effect of Torsion

According to IRC:112-2011, Cl:10.5.2.1 (1), to find the "Design Torsional Shear Force"

Shear stress ($t_{t,i}$)

$$\tau_{t,i} = \frac{T_{Ed}}{2A_k, t_{ef,i}}$$

T_{Ed}	=	2262.5	kN-m	(Combination 1) Table 2
A	=	3934000.0	mm2	
U	=	8410.0	mm	
$t_{ef,i}$	=	467.78	mm	
Ak	=	2185814.8	mm2	
Z_i	=	2800.0	mm	
$t_{t,i}$	=	1.1	N/mm2	

Design torsional shear force ($V_{Ed,i}$)

$V_{Ed,i}$ = $t_{t,i}t_{ef,i}Zi$

= 1.11 x 467.78 x 2800

= 1449113.09 N

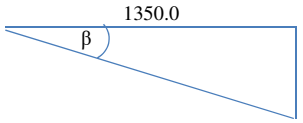
= 1449.11 kN

Total shear force (V_{NS}) = 13,719.98 + 1,449.11

= 15169.09 kN

Shear due to depth of Varying section

(From IS 456-2000 Cl:40.1.1) Shear due to Beams of Varying depth = $\frac{Mu \times \tan\beta}{d}$



β = 0.29

$\tan\beta = \frac{405.00}{1350.00}$ = 0.30

Mu = 8978.7 KNm (Combination 2) Table 3

(From IS 456-2000 $\frac{Mu \times \tan\beta}{d}$ = 2076.79 KN

Resultant Shear Force = VEd-Mu x tan β/d = 13092.30 kN

Check for $V_{Rd.c}$ *(As per Cl 10.3.2 of IRC 112-2011)*

The design shear resistance $V_{Rd.c} \geq V_{Ed.}$

The design shear resistance of the member without shear reinforcement $V_{Rd.c}$ is given by:

$$V_{Rd.c} = \left[0.12K(80\rho_1 . f_{ck})^{0.33} + 0.15\sigma_{cp}\right] b_w . d$$

Subject to a minimum of $v_{Rd.c} = (v_{min} + 0.15\sigma_{cp})\, b_w . d$ **Eq. 10.1**

$K = 1 + \sqrt{\frac{200}{d}} \leq 2.0$ **where** d **is depth in millimeters.** **Eq. 10.2**

and $v_{min} = 0.031K^{3/2} f_{ck}^{1/2}$, **Eq. 10.3**

σ_{cp} **is limited to** $0.2 f_{cd}$ **(MPa) where** $\sigma_{cp} = N_{Ed} / A_c < 0.2 f_{cd}$ **(MPa)**

$\rho_1 = \frac{A_{sl}}{b_w . d} \leq 0.02$ **(Fig. 10.5)**

ρ1 =	0.009		
=	0.009		
K =	1.39		
N_{Ed} =	0.00	KN	
Ac =	3934000.0	mm^2	
σ_p =	0.00	N/mm^2	
$V_{Rd.c}$ =	**2850.68**	**kN**	
V_{Ed} =	13092.30	kN	
$V_{Rd.c}$	<	V_{Ed}	

Hence Shear Reinforcement Required

As per A4.6.1, eq A4.5, IRC:112-2011,

V_{NS} = (ASW / S) * z * fywd * cot θ

f_{ywd} = 435.00 N/mm^2

Spacing (S) required = (ASW * z * fywd * cot θ / VNS

= 171 mm

Assuming

Hence proved **14 L** **Y - 20** **@ 140** **mm c/c**

Check for crushing of concrete (As per Cl 10.3.3.2 of IRC 112-2011)

At the face of Pedestal @ (R1+R3)

VRD.max = **αcw * bw * z * vi * fcd / (cotθ + tanθ)**

VRD.max = Crushing of compressive force for concrete

αcw =	1	
bw =	2800	mm
vi =	0.48	v=0.6*(1-fck/310)
fcd =	26.76	N/mm2
Z =	1167.300	mm

VRD.max = 21160.5 > 14262.2 kN

Hence Safe

Combined Check for Torsion and Shear (As per Cl 10.5.2 (4) of IRC 112-2011)

At the face of Pedestal @ (R1 +R3)

TRd.max = 2v * αcw * fcd * Ak * tef.i * sinθ * cosθ

TEd =	2262.49	kN-m	(Combination 1) Table 2
TRd.max =			
VEd =	13719.98	kN	(Combination 2) Table 3
VRd.max =	21160.51	kN	
v =	0.48		
TRd.max =			
Ak =	2185814.81	mm2	$(b-t_{ef,i}) \times (D-t_{ef,i})$
A=	3934000.00	mm2	
u =	8410.00	mm	
tef.i =	467.78	mm	
TRd.max =	13235.37	kN-m	

(TEd / TRd.max) + (VEd / VRd.max) ≤ 1.0 = 0.819

Hence Safe

Torsional Reinforcement (As per Cl 10.5.2 (5) of IRC 112-2011)

At the face of Pedestal @ (R1+R3)

Ak =	2.19	m2	
T_{ed} =	2262.49	kN-m	(Combination 1) Table 2
u_k =	6.54	m	
fyd =	478.26	N/mm2	

$$\Sigma asl = \frac{T_{Ed} * \cot\theta * uk}{2A_k * fyd}$$

$$\Sigma asl = \frac{2{,}262.49 \times \cot(1) \times 6.54}{2 \times 2.19 \times 47{,}82{,}60{,}869.57}$$

0.0071 m2

7075.93 mm2

However, same shall be compared w.r.t Launching girder erected case and reinforcement corresponding to maximum of 2 conditions shall be provided.

AsL required for Launching girder case = 30001.17

Required Longitudinal reinforcement will be distributed on 4 faces

Ast per face = 7500.292068

Hence Provide **Y - 25** **16 Nos**

Summary of Pier Cap Design:

1	*pier cap size =*	***6000 x***	***2800 x***	***1600 /***	***1000.0***	***mm***
2	*Grade of concrete =*		***M - 60***			
3	*Grade of steel =*		***Fe - 550***			
4	Tension Reinforcement in Transverse Direction =		**32**	**40 Nos**		
4a	Compression Reinforcement in Transverse Direction =		**Y 25**	**20 Nos**		
5	*Vertical stirrups =*		**14 L**	***- Y 20***	**140 c/c**	
6a	*Vertical stirrups =*		**0 L**	***- Y 0***	**140 c/c**	
6	*Torsional Reinforcement*		**Y 25**	**16 Nos**	**on either side of Pier beam in Transverse Direction**	

3) DESIGN OF PIER

Forces at Base of the pier and Foundation bottom:

i) Vehicle on one span for 50.00 m LEFT Span) (Without impact Factor)

Sl No	Vehicle case	R1(kN)	R2(kN)	R1(kN) Lane Reduction	R2(kN) Lane Reduction	Total reaction (kN)(Lane Reduction)	eL (mt)	ML (kNm)	eT (mt)	MT (kNm)
2	2CA+2CA	1015.79	1286.65	812.63	1029.32	1841.95	0.80	1473.56	0.26	487.56
4	70RWL+70RWL	865.94	1234.21	692.76	987.37	1680.12	0.80	1344.10	0.39	662.88

ii) Vehicle on one span for 50.00 m RIGHT Span) (Without impact Factor)

Sl No	Vehicle case	R3(kN)	R4(kN)	R3(kN) Lane Reduction	R4(kN) Lane Reduction	Total reaction (kN)(Lane Reduction)	eL (mt)	ML (kNm)	eT (mt)	MT (kNm)
2	2CA+2CA	1015.79	1286.65	812.63	1029.32	1841.95	0.80	1473.56	0.26	487.56
4	70RWL+70RWL	865.94	1234.21	692.76	987.37	1680.12	0.80	1344.10	0.39	662.88

iii) Vehicle on Both Spans(without imact factor):

Sl No	Vehicle case	R1(kN)	R2(kN)	R3(kN)	R4(kN)	R1(kN) Lane Reduction	R2(kN) Lane Reduction	R3(kN) Lane Reduction	R4(kN) Lane Reduction	Total reaction (kN)(Lane Reduction)
2	2CA+2CA	570.91	321.12	551.30	310.08	500.80	281.68	483.60	272.00	1538.08
4	70RWL+70RWL	628.82	231.37	601.46	221.34	551.60	202.96	527.60	194.16	1476.32

eL (mt)	ML (kNm)	eT (mt)	MT (kNm)
0.8	21.504	0.630	969.12
0.8	26.240	1.040	1534.68

iv A)Braking force from 50.00 m LEFT Span

Sl No	Vehicle case	1st,2nd and 3rdLANE in kN	3rd LANE in kN	1st & 2nd LANE(20%) in kN	3rd LANE(5%) in kN	Total HL in kN	**HL per Trestle (kN)**	**L.A For Pier Base**
2	2CA+2CA	1108.00	1108.00	110.80	55.40	166.20	83.10	17.01
4	70RWL+70RWL	1000.00	1000.00	200.00	50.00	250.00	125.00	17.01

ML @ pier base	**LA for Found^{n}**	**ML @ Found^{n}**	**Add Axial load(kN)**
1413.61	19.11	1588.12	29.207
2126.37	19.11	2388.87	43.933

iv B)Braking force from 50.00 m RIGHT Span

Sl No	**Vehicle case**	**1st,2nd and 3rdLANE in kN**	**3rd LANE in kN**	**1st & 2nd LANE(20%) in kN**	**3rd LANE(5%) in kN**	**Total HL in kN**	**HL per Trestle (kN)**	**L.A For Pier Base**
2	2CA+2CA	1108.00	1108.00	110.80	55.40	166.20	83.10	17.01
4	70RWL+70RWL	1000.00	1000.00	200.00	50.00	250.00	125.00	17.01

ML @ pier base	**LA for Foundn Bottom**	**ML @ Foundn base**	**Add Axial load(kN)**
1413.61	19.11	1588.12	29.207
2126.37	19.11	2388.87	43.933

iv A)Longitudinal Effect:(Frictional force) (From 33.4m LEFT span)

(one Span loaded case(Without impact Factor): Horizontal Force @ Bearing Levl (Single Span)

Sl No	**Vehicle case**	**Fh**	**μ**	**Rg / one side of span**	**Rq (one side of span)**	**μ (Rg + Rq) @ Free Bearing**
2	2CA+2CA	0.00	0.05	8139.44	2019.68	507.96
4	70RWL+70RWL	0.00	0.05	8139.44	1842.24	499.08
						406.97

L.A For Pier Base	**ML @ pier base**	**LA for Found^{n} Bottom**	**ML @ Found^{n} base**	**μ Rg**
17.01	8640.84	19.11	9707.55	406.972
17.01	8489.92	19.11	9537.99	406.972

B)Longitudinal Effect:(Frictional force) (From 33.4m LEFT span)

(Both Span loaded case(Without impact Factor): Horizontal Force @ Bearing Levl (Single Span)

Sl No	**Vehicle case**	**Fh**	**μ**	**Rg / one side of span**	**Rq (one side of span)**	**μ (Rg + Rq) @ Free Bearing**	**L.A For Pier Base**	**ML @ pier base**	**LA for Found^{n} Bottom**	**ML @ Found^{n} base**
2	2CA+2CA	0.00	0.05	8139.44	713.62	442.65	17.01	7529.97	19.11	8459.54
4	70RWL+70RWL	0.00	0.05	8139.44	688.16	441.38	17.01	7508.31	19.11	8435.21

B)Longitudinal Effect:(Frictional force) (From 33.4m RIGHT span)

(One Span loaded case(Without impact Factor): Horizontal Force @ Bearing Levl

Sl No	Vehicle case	Fh	μ	Rg / one side of span	Rq (one side of span)	Fh+μ (Rg + Rq) @ Fixed Bearing
2	2CA+2CA	166.20	0.05	8139.44	2019.68	674.16
4	70RWL+70RWL	250.00	0.05	8139.44	1842.24	749.08

L.A For Pier Base	ML @ pier base	LA for Found^{n} Bottom	ML @ Found^{n} base	μ Rg
17.01	11468.07	19.11	12883.80	406.972
17.01	12742.67	19.11	14315.74	406.972

C)Longitudinal Effect:(Frictional force) (From 33.4m RIGHT span)

(Both Span loaded case(Without impact Factor): Horizontal Force @ Bearing Levl

Sl No	Vehicle case	Fh	μ	Rg / one side of span	Rq (one side of span)	Fh+μ (Rg + Rq) @ Fixed Bearing	L.A For Pier Base	ML @ pier base	LA for Found^{n} Bottom	ML @ Found^{n} base
3	2CA+2CA	166.20	0.05	8139.44	689.11	607.63	17.01	10336.35	19.11	11612.37
5	70RWL+70RWL	250.00	0.05	8139.44	658.25	689.88	17.01	11735.62	19.11	13184.38

v) SELF WEIGHT OF PIER AND PIER SUBSTRUCTURE:

B= 2.8

Pedastal size= 0.2880 m^3

No of pedastal= 4.0

Total sw of pedastal= 28.8 kN

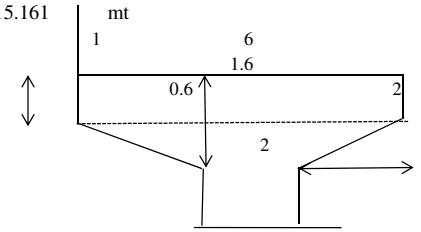
sw of pier beam = 588.0 kN

Area of pier = 4.40 m^2

sw of pier = **1667.7** kN

Total sw = ***2284.5*** kN

Height of pier= 15.161 mt



vi) Wind Force

Wind on Pier Beam :

Width of Pier Cap 2.80 *m* *(b)* *t/b = 2.14*

Height of Pier Cap 1.60 *m* *(h)* *h/b = 0.57*

Length of Pier Cap 6.00 *m* *(t)*

Cd 0.8

Force in Transverse direction = Pz X A1 X G X Cd

A1 = 2.80 *m X* 1.60 *m =* 4.48 *sqm*

Ft = 0.268 X 4.48 X 2 X 0.8

1.92 *kN*

Force in long dirn = 25% *of F transverse =* 0.5 *kN*

Wind on Pier :

Width of Pier	*2.2 m*	*(b)*	*t/b =*	*0.91*	
Height of Pier	*14.6610 m*	*(h)*	*h/b =*	*6.66*	
Length of Pier	*2 m*	*(t)*			
Cd value	*1.33*				

Force in Transverse direction = Pz X A1 X G X Cd

A1 = *2.20 m X* *14.661 m =* *32.2542 sqm*

Ft = *0.268* *X* *32.2542* *X* *2* *X* *1.3345*

23.1 kN

Force in long dirn = *25% of F transverse =* *5.8 kN*

vii) Summary of Wind Load

Wind Force due to DL@ Bearing level	*Lever Arm in mt*	*Transeverse dirction*	*longitudinal dirction*	
Wind force Horizontal due to 50.00 m Left span		*65.637*	*16.41*	
Wind force Horizontal due to 50.00 m Right span span		*65.637*	*16.41*	
Moment at base of pier due to 50.00 m Left span	*17.011*	*1116.55*	*279.14*	
Moment at base of pier due to 50.00 m Right span	*17.01*	*1116.55*	*279.14*	
Moment at base of foundation due to 50.00 m Left span	*19.11*	*1254.38*	*313.60*	
Moment at base of foundation due to 50.00 m Right span	*19.11*	*1254.38*	*313.60*	
Total Horizontal Wind force		*131.3*	*32.8*	*kN*
Total Moment at base of pier		*2233.1*	*558.3*	*kNm*
Total Moment at base of foundn	*19.111*	*2508.8*	*627.2*	*kNm*
Wind on pier Cap		***FT***	***FL***	
Wind force Horizontal		*1.9*	*0.5*	*kN*
Moment at base of pier	*15.961*	*30.7*	*7.7*	*kNm*
Moment at base of foundn	*18.061*	*34.7*	*8.7*	*kNm*
Wind on pier		***FT***	***FL***	
Wind force Horizontal	*m*	*23.1*	*5.8*	*kN*
Moment at base of pier	*7.830*	*180.8*	*45.2*	*kNm*
Moment at base of foundn	*9.930*	*229.3*	*57.3*	*kNm*
Total wind load on DL only		***FT***	***FL***	
Wind force Horizontal		*156.3*	*39.1*	*kN*
Moment at base of pier		*2444.6*	*611.2*	*kNm*
Moment at base of foundn		*2772.8*	*693.2*	*kNm*
Wind due to LL at bearing level		***FT***	***FL***	
Wind force Horizontal due to 50.00 m span		*32.2*	*8.05*	
Wind force Horizontal due to 50.00 m span		*32.2*	*8.05*	
Moment at base of pier due to 50.00 m span	*17.011*	*547.64*	*136.91*	
Moment at base of pier due to 50.00 m span	*17.011*	*547.64*	*136.91*	
Moment at base of foundation due to 50.00 m span	*19.111*	*615.25*	*153.81*	
Moment at base of foundation due to 50.00 m span	*19.111*	*615.25*	*153.81*	
Total Horizontal Wind force		*64.4*	*16.1*	
Total Moment at base of pier		*1095.3*	*273.8*	*kNm*
Total Moment at base of foundn		*1230.5*	*307.6*	*kNm*

Wind force Vertical in kN	*(From Both spans)*		*811.310*	*kN*

ix) Seismic Analysis of Pier Sub Structure:

The seismic analysis is carried out as per the IRC: 6 – 2016 (Cl:219).

Feq = Ah x (Dead Load + Appropriate live load)
Where,
Ah = Horizontal seismic co – efficient
AR = Z.I / 2.R x Sa / g

Z = zone factor =	*0.1*	***(Zone – II)***	(Table-16 of IRC 6-2016)	
R =	*2.5*	(Table-20 of IRC 6-2016)		
I =	*1.2*	(Table-19 of IRC 6-2016)		
Dead Load Rxn =			*16268.88*	***kN***
VLL Rxn =	*20%*	*1538.08*	*307.62*	***kN***
Total =			***16576.496***	***kN***

As Per IRC:6- 2016 *(Annexure-D)*
T=2√W/(1000F)
WL³ / 3EI = *1.0*

W=	*13.049*	***kN***
T=	*2.254*	***Sec***
Sa /g =	*0.444*	

T = *2.25 sec*
Sa /g = 0.444

Ah = *0.1*1.2*0.444/(2*2.5)* ***0.011***

l = Height of pier = *17011* *mm*
Ecm = *16087.0* *N/mm²*

$$I_{gr} = \frac{b \times d3}{12}$$

Igr = 1774666666667 *mm⁴*
I_{eff} = *1.331E+12* *mm⁴*
(0.75 x Igr)

Ecm = 37000 MPa (as per IRC-112, table-6.5)

As per IRC:112-2011, table-6.9, for RH-50%, & 28 days age loading

ø 1=	1.7	for	150
ø 2=	1.5	for	600
ø =	**1.30**	for	1048

Ec,eff = 16086.96 MPa 2Ac/u = 1047.62

i) Longitudinal direction:(Dead Loads)

Sl No	Component	Total vertical Load in kN	**Total Seismic load (Long-HL)**	
1	DL	16268.88	**173.21**	
2	Pier cap	700.00	7.45	
3	pedastals	28.80	0.31	
4	Pier	1667.71	17.76	

ii) Transeverse direction:(Dead Loads)

Sl No	Component	Total vertical Load in kN	**Seismic load (Trans-HT)**	
1	DL	16268.88	**173.21**	
2	Pier cap	700.00	**7.45**	
3	pedastals	28.80	**0.31**	
4	Pier	1667.71	**17.76**	

iii) Vertical direction:(Dead Loads)

Sl No	Component	Total vertical Load in kN	**Seismic load (Vertical-Vs)**	
1	DL	16268.88	**115.48**	
2	Pier cap	700.00	**4.97**	
3	pedastals	28.80	**0.20**	
4	Pier	1667.71	**11.84**	

Seismic in Longitudinal Direction due to 50.00 m span						**Total ML @ pier base**	**Total ML @ Pile Cap bottom**
Component	**HL**	LA w.r.to pier base	**ML @ pier base**	LA w.r.to pier base	**ML @ Pile Cap bottom x 1.35**		
DL	173.21	18.3670	3181.43	20.4670	4786.00	**3181.43**	**4786.0**
Pier cap	7.45	15.8610	118.21	17.9610	180.71	**118.21**	**180.7**
pedastals	0.31	16.7610	5.14	18.8610	7.81	**5.14**	**7.8**
Pier	17.76	7.5805	134.60	9.6805	232.05	**134.60**	**232.0**

Seismic Transverse Direction due to 50.00 m span						**Total MT @ pier base**	**Total MT @ Pile Cap bottom**
Component	**HT**	LA w.r.to pier base	**MT @ pier base**	LA w.r.to pier base	**MT @ Pile Cap bottom x 1.35**		
DL	173.21	18.367	3181.43	20.47	4786.00	**3181.43**	**4786.0**
Pier cap	7.45	15.861	118.21	17.96	180.71	**118.21**	**180.7**
pedastals	0.31	16.761	5.14	18.86	7.81	**5.14**	**7.8**
Pier	17.76	7.580	134.60	9.68	232.05	**134.60**	**232.0**

Note: ***1.35*** For design of foundation, the seismic loads should be taken as 1.35 times the forces transmitted to it by concrete substructure.(219.8 of IRC 6-2014)

iv) Vehicle on one span(Without impact Factor) Seismic case: for 50.00 m LEFT Span

Sl No	Vehicle case	**Seismic load (Vertical-V_s)**	**Seismic load (Long-HL)**	**Seismic load (Trans-HT)**	lever arm w.r t.pier base	**MT (kNm) pier base due to seismic**	**MT due to VLL Eccentricity**
2	2CA+2CA	**354.560**	**0.000**	**3.775**	17.011	**64.22**	**97.51**
4	70RWL+70RWL	**320.000**	**0.000**	**3.407**	17.011	**57.96**	**132.58**

LA w.r.to Found^{n} Bottom	**MT (kNm) Pile Cap bottom (due to seismic) x 1.35**	**Total MT @ Pile Cap Base**	**ML due toVLL Eccentricity (kN-m)**
19.111	**97.39**	**194.91**	**294.71**
19.111	**87.90**	**220.48**	**268.82**

v) Vehicle on one span(Without impact Factor) Seismic case: for 50.00 m RIGHT Span

Sl No	Vehicle case	**Seismic load (Vertical-V_s)**	**Seismic load (Long-HL)**	**Seismic load (Trans-HT)**	lever arm w.r t.pier base	**MT (kNm) pier base due to seismic**	**MT due to VLL Eccentricity**
2	2CA+2CA	**354.56**	**0.000**	**3.775**	17.011	**64.22**	**97.51**
4	70RWL+70RWL	**320.00**	**0.000**	**3.407**	17.011	**57.96**	**132.58**

LA w.r.to Found^{n} Bottom	**MT (kNm) Pile Cap bottom due to seismic x 1.35**	**Total MT @ Pile Cap Base**	**ML due to VLL Eccentricity (kN-m)**
19.111	**97.39**	**194.91**	**294.71**
19.111	**87.90**	**220.48**	**268.82**

vi) Vehicle on Both Span (without imact factor):

Sl No	**Vehicle case**	**Seismic load (Vertical-V_s)**	**Seismic load (Long-HL)**	**Seismic load (Trans-HT)**	L Arm W.r t.pier base	**MT (kNm) pier base due to seismic**	**MT Due toVLL Eccentricity**
2	2CA+2CA	**354.56**	**0.000**	**3.77**	17.011	64.216	**193.82**
4	70RWL+70RWL	**320.00**	**0.000**	**3.41**	17.011	57.957	**306.94**

LA W.r t.Found Bottom	**MT (kNm) Pile Cap bottom due to seismic x 1.35**	**ML Due to VLL Eccentricity**
19.111	**97.39**	**4.301**
19.111	**87.90**	**5.248**

vi)Braking force(seismic case): 50.00 m LEFT Span

Sl No	Vehicle case	1st & 2nd LANE in kN	3rd & 4th LANE in kN	HL in 1st & 2nd LANE(20%) in kN	HL in 3rd & 4th LANE(5%) in kN	ML=HL x 0.2 x L.A in kNm	Add Axial load(kN)	**HL per Trestle x 0.20 in kN**	LA at pier base
2	2CA+2CA	1108.0	1108.0	221.6	55.4	219.6	4.54	**27.7**	17.01
4	70RWL+70RWL	1000.0	1000.0	200.0	50.0	198.2	4.10	**25.0**	17.01

LA at footing bottom	**ML @ Pier bottom**	**ML @ Pile Cap bottom**
19.111	**471.20**	**529.37**
19.111	**425.27**	**477.77**

v)Braking force(seismic case): 50.00 m RIGHT Span

Sl No	Vehicle case	1st & 2nd LANE in kN	3rd & 4th LANE in kN	HL in 1st & 2nd LANE(20%) in kN	HL in 3rd & 4th LANE(5%) in kN	ML=HL x 0.2 x L.A in kNm	Add Axial load(kN)	**HL per Trestle x 0.20 in kN**	LA at pier base
2	2CA+2CA	1108.0	1108.0	221.6	55.4	219.6	4.54	**27.7**	17.01

4	70RWL+70RWL	1000.0	1000.0	200.0	50.0	198.2	4.10	**25.0**	17.01

LA at footing bottom	**ML @ Pier bottom**	**ML @ Pile Cap bottom**
19.111	**471.20**	**529.37**
19.111	**425.27**	**477.77**

viA)Frictional (seismic case): 50.00 m LEFT Span

One Span loaded case(Without impact Factor): Horizontal Force @ Bearing Levl (seismic due to VLL is not considered in the direction of traffic (longitudinal direction) as per IRC 6-2014)

Sl No	Vehicle case	Fh x 0.2	**μ**	**Rg / one side of span**	**Rq (one side of span)**	**μ (Rg + Rq) @ Free Bearing**	**μ (Rg)**	L.A For Pier Base
2	2CA+2CA	0.0	0.05	8139.4	403.9	**427.2**	**406.97**	17.011
4	70RWL+70RWL	0.0	0.05	8139.4	368.4	**425.4**	**406.97**	17.011

ML @ pier base	LA w.r.to Pile CapBottom	**ML @ Pile Cap bottom**
7266.6	19.111	**8163.6**
7236.4	19.111	**8129.7**

B)Frictional force(seismic case): 50.00 m Left Span

Both Span loaded case(Without impact Factor): Horizontal Force @ Bearing Levl (seismic due to VLL is not considered in the direction of traffic (longitudinal direction) as per IRC 6-2014)

Sl No	Vehicle case	**Fh x 0.2**	**μ**	**Rg / one side of span**	**Rq (one side of span)**	**μ (Rg + Rq) @ Free Bearing**	**μ (Rg)**	L.A For Pier Base
2	2CA+2CA	0.0	0.05	8139.4	713.6	**442.7**	**406.97**	17.011
4	70RWL+70RWL	0.0	0.05	8139.4	688.2	**441.4**	**406.97**	17.011

ML @ pier base	LA w.r.to Pile CapBottom	**ML @ Pile Cap bottom**
7530.0	19.111	**8459.5**
7508.3	19.111	**8435.2**

C)Frictional force(seismic case): 50.00 m RIGHT Span

One Span loaded case(Without impact Factor): Horizontal Force @ Bearing Levl

Sl No	Vehicle case	Fh x 0.2	**μ**	**Rg / one side of span**	**Rq / one side of span x 0.2**	**Fh+μ (Rg + Rq) @ Fixed Bearing**	**μ (Rg)**	L.A For Pier Base
2	2CA+2CA	33.2	0.05	8139.4	403.9	**460.4**	**406.97**	17.011
4	70RWL+70RWL	50.0	0.05	8139.4	368.4	**475.4**	**406.97**	17.011

ML @ pier base	LA w.r.to Pile CapBottom	**ML @ Pile Cap bottom**
7832.0	19.111	**8798.9**
8086.9	19.111	**9085.3**

D)Frictional force(seismic case): 50.00 m RIGHT Span

Both Span loaded case(Without impact Factor): Horizontal Force @ Bearing Levl

(seismic due to VLL is not considered in the direction of traffic (longitudinal direction) as per IRC 6-2014)

Sl No	Vehicle case	Fh x 0.2	μ	Rg / one side of span	Rq / one side of span x 0.2	Fh+μ (Rg + Rq) @ Fixed Bearing	μ (Rg)	L.A For Pier Base
2	2CA+2CA	33.2	0.05	8139.4	137.8	**447.1**	**406.97**	17.011
4	70RWL+70RWL	50.0	0.05	8139.4	131.6	**463.6**	**406.97**	17.011

ML @ pier base	LA w.r.to Pile CapBottom	ML @ Pile Cap bottom
7605.7	19.111	**8544.6**
7885.5	19.111	**8859.0**

DESIGN OF PIER:

A). PIER LOAD COMBINATIONS

C1 to C6 = *DL+VLL ON ONE SPAN (WITH OUT IF)+(BF + SF)*

C7 to C12 = *DL+VLL ON BOTH SPAN (WITH OUT IF)+(BF + SF)*

C13 to C18 = *DL+VLL ON ONE SPAN (WITH OUT IF)+(BF + SF) +WIND ON SUPER STRUCTURE +WIND ON LIVE LOAD +WIND ON PIER CAP +WIND ON PIER*

C18 to C24 = *DL+VLL ON BOTH SPAN (WITH OUT IF)+(BF + SF)+WIND ON SUPER STRUCTURE +WIND ON LIVE LOAD +WIND ON PIER CAP +WIND ON PIER*

C25 = *DL+SW+WIND ON UNLOADED STURCTURE*

C26 = *Launching Girder Case*

The Pier section is designed as a circular section subjected to axial force and bending using SP-16, Design Aids For IS 456. The results are tabulated below:-

Load Factors as per IRC 6-2016 Table B.2

Sl Nos	Loads	VLL is Leading & Wind is accompanying	Wind is Leading & VLL is
1)	SW =	1.35	1.35
2)	SIDL(W/o WC) =	1.35	1.35
3)	WC =	1.75	1.75
4)	VLL =	1.5	1.15
5)	BRAKING FORCE =	1.5	1.15
6)	WIND =	0.9	1.5
7)	Seismic =	1.5	-

i) Normal and Wind Combination (Factored Loads)

COMB	P in kN	ML in kNm	MT in kNm
C2	28778.78	30620.56	3917.26
C4	28558.13	32346.50	4180.24
C8	28322.98	27655.35	4639.60
C10	28252.43	29737.11	5487.94
C14	28610.66	24449.30	5870.56
C16	28441.50	25518.34	6072.18
C20	28261.21	21921.79	6424.36
C22	28207.12	23517.81	7074.75
C25	25940.66	1901.11	916.74
C26	22380.09	19805.87	0.00

ii) Seismic Combinations (Factored Loads) (As per Cl:219.4 of IRC 6-2016))

C1 = DL+SW of pier + Secondary Force (P+ML +0.3MT) *Seismic in Longitudinal direction*

C2 to C7 = DL+0.2xVLL (with out IF) one span+0.2x(BF , FF) (P+ 0.3ML+ MT)

C7 to C13 = DL+0.2xVLL (with out IF) both span+0.2x(BF,FF) (P+ 0.3ML+ MT) } *Seismic in Transverse direction*

Seismic Forces in Longitudinal Direction

Combinations	P in kN	M_{L1} in kNm	M_{T1} in kNm
C1	25790.53	12534.94	1746.59

Seismic Forces in Transverse Direction

Combinations	P in kN	M_{L2} in kNm	M_{T2} in kNm
C3	26326.45	24133.11	5401.66
C5	26276.67	24476.65	5444.87
C9	26330.54	24739.64	5546.13
C11	26282.81	25082.43	5706.41

PIER LOAD COMBINATIONS (QUASI PERMANENT COMBINATION-Table No B.3 of IRC6-2016)

(PARTIAL SAFETY FACTOR TAKEN AS PER IRC:6,2014, TABLE NO 3.3)

Sl Nos	*Loads*	*VLL is Leading & Wind is accompanying*	*Wind is Leading & VLL is accompanying*
1)	*SW =*	***1.00***	1
2)	*SIDL(W/o WC) =*	***1.00***	1
3)	*WC =*	***1.00***	1
4)	*VLL =*	***0.00***	0
5)	*BRAKING FORCE =*	***0.00***	*0*
6)	*WIND =*	***0.00***	*0*
7)	*Seismic =*	-	-

COMB	P in kN	ML in kNm	MT in kNm	Design BM = $\sqrt{(ML^2+MT^2)}$
C1	18553.39	6933.80	0.00	6933.80

Check for Slenderness Ratio

Size of Pier 2200.000 x 2000.000 *mm*

Clear cover = = 40.00 *mm*

Grade of Concrete = M - 60

Grade of Steel = = Fe - 550

As per IRC:112-2011, The minimum Ast for Pier is as follows,
1). (Length / radius of gyration) < 12 is "Pedestrian Column"
2). (Length / radius of gyration) > 12 is "Other Column"

Radius of Gyration (Rg) = Sqrt(I/A)

Rg = 635

I= 1.77467E+12 mm4

A = 4400000 mm2

Length of pier (Le) = 20034 *Effective lengthas per IRC:112-2011,Table 11.1,pg no 114, = l_0 *1.3*

Slenderness ratio L / Rg = 31.55 **HENCE IT IS 'OTHER COLUMN'**

As per 11.2.2 of IRC 112-2011,Effective Length of Pier

(1) For compression members in regular frames, the effective length l_e is determined in the following way:

Braced Members:

$$l_e = 0.5 l_o \sqrt{\left(1+\frac{k_1}{0.45+k_1}\right) x \left(1+\frac{k_2}{0.45+k_2}\right)} \qquad \text{Eq.11.2}$$

Unbraced members:

$$l_e = l_o \; x \max of \left\{ \sqrt{\left(1+10.\frac{k_1.k_2}{k_1+k_2}\right)} ; \left(1+\frac{k_1}{1+k_1}\right) x \left(1+\frac{k_2}{1+k_2}\right) \right\} \qquad \text{Eq.11.3}$$

K1 = 0.1

K2 = 0.1

$$\sqrt{1+\frac{10.K1.K2}{K1+K2}} \; / \; 1+\frac{K1}{(1+K1)} \; x \; (1+\frac{K2}{(1+K2)} = 1.22 / 1.190$$

l_o = 15411 mm

l_e = 18.87 m

Limiting Slenderness ratio as per IRC:112-2011, Cl:11.2.1(2),

Limiting Slenderness ratio as per IRC:112-2011, Cl:11.2.1(2)

λ_{lim} = 20.A.B.C / sqrt(n)

n= N_{Ed} / (Ac*fcd)

N_{Ed}= 28778.78 kN

Ø ef= $\varphi(\infty,t_0).M_{oEqp}/M_{oEd}$

$\varphi(\infty,t_0)$ = *1.636* *(As per IRC 112-2011,A2.5)*

Mo_{Eqp} = *6933.80* KNm

Mo_{ED} = *32346.50* KNm

Ø ef= 0.351

A= 0.934

w= 0.359

n= 0.24

B= 1.311

C= 0.7

λ_{lim} = 34.71 > 18.87

Hence OK

Ac= 4400000 mm²

h= 2.Ac /U = 1047.6 mm

fcd= 26.80 N/mm²

n= 0.24

Second order effects may be ignored if the slenderness ratio λ based on l_e as per Clause 11.2.2 is less than a certain value λ_{lim} as per Eq.11.1.

$$\lambda_{lim} = 20.A.B.C / \sqrt{n} \qquad \text{Eq.11.1}$$

where

A = $1/(1+0.2\phi_{ef})$

ϕ_{ef} *is effective creep ratio.*

$\phi_{ef} = \phi(\infty,t_o).\frac{M_{oEqp}}{M_{oEd}}$

M_{oEqp} *= First order B.M. in quasi-permanent load combination in SLS.*

M_{oEd} *= First order B.M. in design load combination in U.L.S.*

B = $\sqrt{1+2\omega}$

C = $1.7 - r_m$

ω = $A_s f_{yd} / (A_c f_{cd})$ *mechanical reinforcement ratio.*

A_s = *is the total area of longitudinal reinforcement.*

n = $N_{Ed} / (A_c f_{cd})$ *relative normal force*

r_m = M_{01} / M_{02} *moment ratio*

M_{01}, M_{02} are the first order end moments at two ends of member as calculated from the analysis of structure, where $|M_{02}| \geq |M_{01}|$.

If the end moments M_{01} & M_{02} give tension on the same side, r_m should be taken positive (i.e. C ≤ 1.7), otherwise negative (i.e. C >1.7).

In the following cases, r_m should be taken as 1.0 (i.e. C = 0.7):

- For unbraced members in general.
- For braced members in which the first order moments arise predominantly from imperfections or transverse loading.

Limiting Slenderness ratio as per IRC:112-2011, Cl:11.2.1(2) (Direct Calculation)

λ_{lim} = 20.A.B.C / sqrt(n)

n= N_{Ed} / (Ac*fcd)

A= 0.70

B=	1.10		
C=	0.70		
Ac=	4400000	mm2	
fcd=	26.80	N/mm2	**(α*fck/λ_m)** *cl:6.4.2.8(1)*
N_{Ed}=	28778.78	kN	
n=	0.24		
λ_{lim} =	21.82		
<	18.87		**Hence OK**

Design of Vertical Reinforcement

Check for design of Bi-axial Column (For Rectangular column)

As per 8.3.2(4)of IRC 112-2011, Pg no 75
For Rectangular column,

$$\left(\frac{M_{Edx}}{M_{Rdx}}\right)^{\alpha}+\left(\frac{M_{Edy}}{M_{Rdy}}\right)^{\alpha}\le 1 \qquad \text{Eq. 8.3}$$

where
M_{Edx}, M_{Edy} Design moment around the respective axis, including nominal 2nd order moments.
M_{Rdx}, M_{Rdy} Moment resistance in the respective direction
Exponent as follows;
- for circular and elliptical cross-sections: $\alpha = 2$
- for rectangular cross-sections:

N_{Ed}/N_{Rd}	0.1	0.7	1.0
α =	1.0	1.5	2.0

With linear interpolation for intermediate values.
N_{Ed}= design value of axial force.
$N_{Rd}= A_c f_{cd} + A_s f_{yd}$, design axial resistance of section.

Size of Pier = 2000 x 2200.00

Combinations	Normal Combination			Seismic Longitudinal	Seismic Transverse	As per SP-16, Cl 3.3, Pg no 104,
Grade of Concrete	60			60.00	60	N/mm2
Grade of Steel	550			550.00	550	N/mm2
b	2000.00			2000.00	2000.00	
d	2200.00			2200.00	2200.00	
Combinations	C2	C4	C21	C1	C10	
Pu	28778.78	28558.13	27560.36	25790.53	26100.36	kN
Mux	30620.56	32346.50	22030.73	12534.94	24347.03	kN-m
Muy	3917.26	4180.24	10471.67	1746.59	6559.96	kN-m
d'/D	0.032			0.032	0.032	
α	1.07	1.07	1.06	1.05	1.05	(for Rectangular as per IRC:112-2011, Cl:8.3.2, Pg no 75)
Assume Pt	**1.800**	**1.800**	**1.800**	**1.800**	**1.800**	
Ast Required (As pro)	79200.0	79200.0	79200.0	79200.0	79200.0	
p / fck	0.0300	0.0300	0.0300	0.0300	0.0300	
Pu/(fck*b*D)	0.109	0.108	0.104	0.098	0.099	
Mu/(fck*b*D*D)	0.080	0.080	0.080	0.080	0.080	(from Chart 47, using SP-16)
Mu/(fck*D*b*b)	0.080	0.080	0.080	0.080	0.080	(from Chart 47, using SP-16)
Mu (Longer Direction)	46464.0	46464.0	46464.0	46464.0	46464.0	kN-m
Mu (shorter Direction)	42240.0	42240.0	42240.0	42240.0	42240.0	kN-m (Resisting moment for provided steel)
Interaction ratio	$\left(\frac{M_{Edx}}{M_{Rdx}}\right)^{\alpha}+\left(\frac{M_{Edy}}{M_{Rdy}}\right)^{\alpha}\le 1$			(12,534.94/46,464.00) ^1.05 + (1,746.59/42,240.00) ^1.05	(24,347.03/46,464.00) ^1.05 + (6,559.96/42,240.00) ^1.05	
				0.25 + 0.04	0.51 + 0.14	
	0.72	**0.76**	**0.68**	= 0.29	= 0.65	< 1.00

	Hence O.K			Hence O.K	Hence O.K	
Total Area of steel required	79200	79200	79200	79200	79200	mm^2
Ast Provided =	Y32	-	106 Nos	Y32 - 106 Nos	Y32 - 106 Nos	
	84848.1			84848.1	84848.1	
Total Area of Steel provided	84848.13			84848.13 mm^2	84848.13 mm^2	
Provided pt	1.986			1.986	1.986	
	Hence O.K			Hence O.K	Hence O.K	

As per IRC 112-2011 Cl:16

Ast.Min =	6619.119 mm^2	$0.1N_{Ed}/f_{yd}$
Ast.Min =	8800 mm^2	0.002 Ac
Ast.Min =	10560 mm^2	0.0024 Ac
Ast.Max =	176000 mm^2	0.004Ac

Lateral ties

As per IRC:112-2011, Cl:16.2.3,

Dia of lateral tie is max of below,

i). 8 mm

ii). One quarter of max dia of longitudinal bars 8 mm

Hence provide 8 mm

Spacing of lateral tie is min of below,

i). 12 times min dia of longitudinal bars 384.00 mm

ii). The least dimension of the column 1555.63 mm

iii). 200 mm 200.00 mm

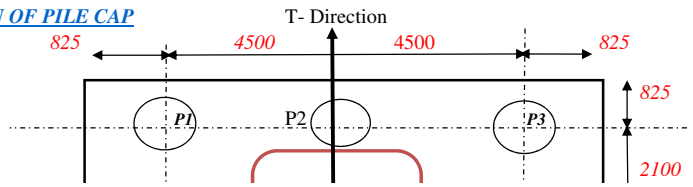
Hence provide 150 mm

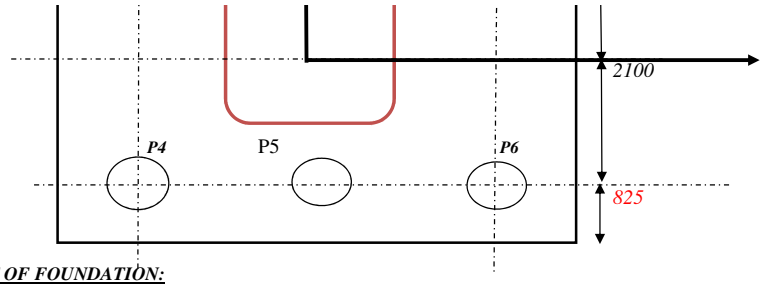
Hence provide Y - 8 @ 150 c/c

Summary

1	*Pier Size =*	*(Circular Pier*	2200 mm Dia)	
2	*Grade of concrete =*		*M - 60*	
3	*Grade of steel =*		*Fe - 550*	
4	*Main Longitudinal reinforcement=*		***Y- 32 of 25 Nos***	**per each face of Wall**
5	*Lateral Ties =*		***Y - 8 @ 150 c/c***	**above the confinement reinforcemnt.**

4) DESIGN OF PILE CAP





SELF WEIGHT OF FOUNDATION:

Width of Pile Cap =	*10650.0*	*mm*
Length of Pile Cap =	*5850.0*	*mm*
Thickness of Pile Cap =	*2100.0*	*mm*
Height of soil =	*300.0*	*mm*
Sw of the Pile Cap=	*3270.9*	*kN*
Wt of soil =	*347.4*	*kN*

Load Factors as per IRC 6-2016 Table B.3

Sl Nos	Loads	VLL is Leading & Wind is accompanying	Wind is Leading & VLL is accompanying
1	SW =	1	1
2	SIDL(W/o WC) =	1	1
3	WC =	1.2	1.2
4	VLL =	1	0.75
5	BRAKING FORCE =	1	0.75
6	WIND =	0.6	1
7	Seismic =	1	-

Load Combinations

C1 to C6 = *DL+VLL ON ONE SPAN (WITH OUT IF)+(BF + FF)*

C7 to C12 = *DL+VLL ON BOTH SPAN (WITH OUT IF)+(BF + FF)*

C13 to C18 = *DL+VLL ON ONE SPAN (WITH OUT IF)+(BF + SF) +WIND ON SUPER STRUCTURE +WIND ON LIVE LOAD +WIND ON PIER CAP +WIND ON PIER*

C18 to C24 = *DL+VLL ON BOTH SPAN (WITH OUT IF)+(BF + SF)+WIND ON SUPER STRUCTURE +WIND ON LIVE LOAD +WIND ON PIER CAP +WIND ON PIER*

C25 = *DL+SW+WIND ON UNLOADED STURCTURE*

C26 = *Launching Girder Case*

i) Normal and Wind Combination (Unfactored Loads)

Combinations	P in kN	M_L in kNm	M_T in kNm	HL	HT	H=√HL^2+HT^2	H/Pile	*Remarks*
C2	24529.6	22743.5	2889.6	1114.2	132.4	1122.069	187.0115	Normal Comb
C4	24382.5	24046.0	3064.9	1189.2	132.4	1196.506	199.4177	Normal Comb
C8	24225.8	20701.9	3371.1	1083.4	132.4	1091.443	181.9072	Normal Comb
C10	24178.7	22254.3	3936.7	1164.4	132.4	1171.870	195.3117	Normal Comb
C14	24386.4	17610.1	4369.0	866.0	220.7	893.690	148.9483	Wind Comb
C16	24276.0	18586.9	4500.5	922.2	220.7	948.247	158.0412	Wind Comb
C20	24158.5	16062.8	4730.2	842.9	220.7	871.289	145.2149	Wind Comb
C22	24123.2	17223.5	5154.3	903.6	220.7	930.174	155.0290	Wind Comb
C25	24521.1	701.2	693.2	55.2	220.7	227.470	37.9117	Wind Comb
C26	16577.8	15070.5	0.0	190.3	0.0	190.250	31.7083	

ii) Seismic Combinations (Unfactored Loads)

C1 = DL+SW of pier + Secondary Force (P+ML +0.3MT) *Seismic in Longitudinal direction*

C2 to C7 = DL+0.2xVLL (with out IF) one span+0.2x(BF , FF) (P+ 0.3ML+ MT)

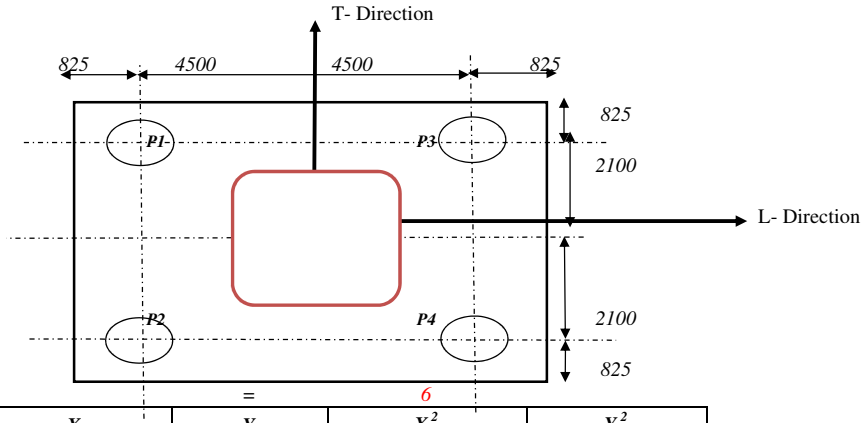
C7 to C13 = DL+0.2xVLL (with out IF) both span+0.2x(BF,FF) (P+ 0.3ML+ MT) } *Seismic in Transverse direction*

Seismic Forces in Longitudinal Direction

combinations	P in kN	M_L in kNm	M_T in kNm	HL	HT	H=√HL^2+HT^2	H/Pile	Remarks

C1	22462.54	13286.92	1694.55	614.63	183.55	641.454	106.9090	Seismic
Seismic Forces in Transverse Direction								
C3	22819.83	18441.20	5401.47	947.87	272.06	986.138	164.3563	Seismic
C5	22786.64	18701.69	5427.04	962.85	271.69	1000.450	166.7417	Seismic
C9	22822.55	18578.40	5497.78	974.54	272.06	1011.806	168.6343	Seismic
C11	22790.73	18869.42	5601.40	990.67	271.69	1027.249	171.2081	Seismic

CALCULATION OF PILE REACTION AND DESIGN OF PILE CAP



Number of piles = 6

Pile No.	*X*	*Y*	X^2	Y^2
1	-4.50	2.10	20.25	4.41
2	0.00	2.10	0.00	4.41
3	4.50	2.10	20.25	4.41
4	-4.50	-2.10	20.25	4.41
5	0.00	-2.10	0.00	4.41
6	4.50	-2.10	20.25	4.41
			81.00	26.46

Pile Reactions

i) Normal and Wind Combination (Unfactored Loads)

COMB	P in kN	M_L in kNm	M_T in kNm	Pmax	Pmin	Remarks
C2	24529.6	22743.5	2889.6	5581.1	2595.4	*Normal Comb*
C4	24382.5	24046.0	3064.9	5642.9	2484.6	*Normal Comb*
C8	24225.8	20701.9	3371.1	5455.3	2620.0	*Normal Comb*
C10	24178.7	22254.3	3936.7	5578.6	2481.0	*Normal Comb*
C14	24386.4	17610.1	4369.0	5389.5	2739.3	*Wind Comb*
C16	24276.0	18586.9	4500.5	5435.8	2656.2	*Wind Comb*
C20	24158.5	16062.8	4730.2	5294.2	2758.6	*Wind Comb*
C22	24123.2	17223.5	5154.3	5386.5	2654.6	*Wind Comb*
C25	24521.1	701.2	693.2	4180.8	3992.9	*Wind Comb*
C26	20196.14	15070.54	0.00	4203.3	2528.8	

Maximum And Minimum Pile Loads

Max	Min

Max Pile Load	***Pile Capacity***

Normal Load Combination	5642.89kN	2233.27kN
Wind Combination	5493.47	2406.99

5642.9kN	< 6000.00	(Normal Load combination)
5493.5kN	< 1.25x 6000.00	(Wind Load Combination)

ii) Seismic Combinations (Unfactored Loads)

COMB	P in kN	ML in kNm	MT in kNm	Pmax	Pmin
C1	22462.5	13286.9	1694.5	4616.4	2871.1
C3	22819.8	18441.2	5401.5	5256.5	2350.1
C5	22786.6	18701.7	5427.0	5267.5	2328.1
C9	22822.5	18578.4	5497.8	5272.2	2335.3
C11	22790.7	18869.4	5601.4	5291.3	2305.6

Maximum And Minimum Pile Loads

Max	Min
5291.31kN	2268.10kN

Max Pile Load	*Pile Capacity*	
5291.31kN	< 1.25x 6000.00	(Seismic Load combination)

iii) Normal and Wind Combination (Factored Loads)

COMB	P in kN	ML in kNm	MT in kNm	Pmax	Pmin
C2	33715.59	34114.04	4334.34	7858.49	3380.05
C4	33494.94	36067.78	4597.32	7951.12	3213.86
C8	33259.79	31051.67	5056.68	7669.72	3416.88
C10	33189.24	33380.30	5905.02	7854.65	3208.43
C14	33547.47	25505.15	6565.70	7529.29	3653.21
C16	33378.31	27164.09	6767.32	7609.26	3516.85
C20	33198.03	24619.48	7119.50	7465.79	3600.22
C22	33143.94	26404.76	7769.89	7607.58	3440.40
C25	31343.53	2090.43	1039.82	5422.58	5025.26
C26	27264.79	20345.22	0.00	5674.42	3413.84

Maximum And Minimum Pile reactions

	Max	Min
Normal Load Combination	7951.12kN	2836.83kN
Wind Combination	7676.88kN	3155.51kN

iv) Seismic Combinations (Factored Loads)

COMB	P in kN	ML in kNm	MT in kNm	Pmax	Pmin
C1	30923.20	19926.38	2342.95	6446.84	3860.90
C3	31489.48	27660.59	8102.21	7427.98	3068.52
C5	31437.64	28051.34	8140.56	7444.09	3035.12
C9	31526.92	27859.95	8246.67	7456.76	3052.21
C11	31483.71	28386.36	8402.10	7491.14	3003.43

Maximum And Minimum Pile reactions

Max	Min
7496.77kN	2934.73kN

Design of pile cap:

PILE CAP FOR 4 PILE GROUP

Pile Spacing in L direction	=	9.00 m
Pile Spacing in T direction	=	4.20 m
Pile diameter	=	1.35 m
Distance between edge of pile to edge of pile cap	=	0.15 m

Depth of pile cap	=	2.1 m
Pile cap dimension along L direction	=	10.65 m
Pile cap dimension along T direction	=	5.85 m
Grade of concrete	=	M - 35 Mpa
Grade of steel	=	550 Mpa

Pile reaction:

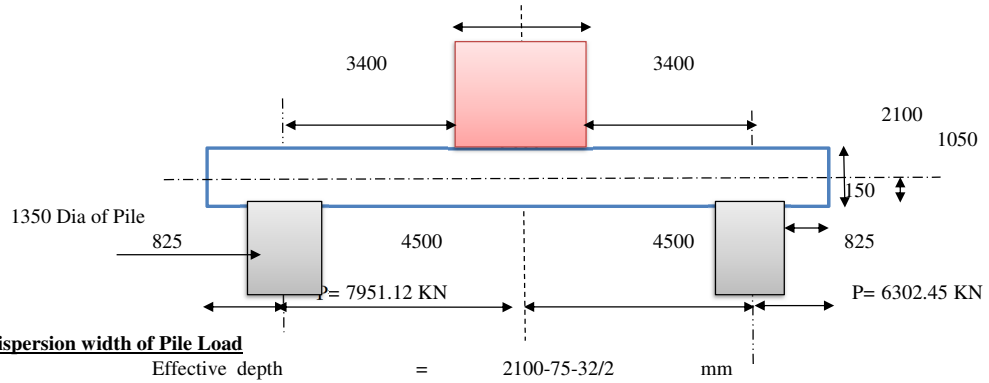
Critical pile reaction:

Pile Name	Pmax	Pmin
Pile Loads for Design of Pile Cap	7951.12	5025.26

P7 P8 P9
5619.27 5619.27 5619.27

Bending Moment in Longitudinal Direction

Since the Pile reaction of individual piles does not overlap at mid depth of the Pile cap, Forces are calculated w.r.t maximum reaction and same forces considered for the design of Pile cap in both Longitudinal and transverse direction.



a) Dispersion width of Pile Load

Effective depth	=	2100-75-32/2	mm
Effective depth	=	2009	mm

Clear Distance between pile to pile = 6300mm > 1050mm

Hence Dispersion Dose not over lap

Effective width of dispersion	=	150+1350+1050	
	=	2550	mm
Pile reaction	=	7951.12	kN
Bending Moment	=	7,951.12x3.400=	27033.82 kNm
B.M /meter Width =		10601.50	

b) Bending moment due to dispersion of Pier Load

Maximum Axial force for Pier (Factored Combinations) =	=	28778.8 KN	
Width of dispersion from Pier on pile cap (B_{eff})	=	2200+1050+1050	= 4300 mm
Dispersed Area of Pier	=	8.600 m^2	
Pier Load per dispersed area of pier (factored)	=	3346.37 KN/m^2	

Moment due to this load =	=	3346.37x1.05X1.05/2	=	0.0	KNm/m	
Resultant Moment due to Pile Load and Pier load	=	**10601.50 KNm/m**				
Grade of Concrete	=	**35** Mpa				
Grade of steel	=	**550** Mpa				
Clear cover	=	**75** mm				
Dia of main bar	=	**32** mm				

Effective depth required = $\sqrt{\dfrac{10601 \times 1000000}{0.133 \times 35 \times 1000}}$

= 1509.12 mm

Effective depth provided = 1977 mm > **SAFE**

Ast required = 12442.98 mm^2

As per IRC:112-2011, Cl:16.5.1.1, Pg no 175, (Table 6 of IRC 112) fctm = 2.8

Ast max is not greater than **0.025 Ac**	Ast min =	0.0013* b*d	2570.10 mm2
Total Ast + Asc is not greater than **0.04 Ac**	Ast min =	0.26*fctm *b.d/fyd	3025.34 mm2

Hence **Required A_{st}** = **12442.98** mm2

Provide Y - 32 @ + Y - 32 @ 100 C/C Ast $_{Provided}$ = 16085.0 **HENCE O.K**

Check for ultimate shear Resistence

As per Cl:10.3.2 IRC 112, Check for Ultimate Shear resistence is given by

1) The design shear resistance $V_{Rd.c} \geq V_{Ed}$

2) The design shear resistance of the member without shear reinforcement $V_{Rd.c}$ is given by:

$$V_{Rd.c} = \left[0.12K(80\rho_1 . f_{ck})^{0.33} + 0.15\sigma_{cp}\right] b_w.d$$

Subject to a minimum of $v_{Rd.c} = (v_{min} + 0.15\sigma_{cp})\, b_w.d$ **Eq. 10.1**

$K = 1 + \sqrt{\frac{200}{d}} \leq 2.0$ where d is depth in millimeters. **Eq. 10.2**

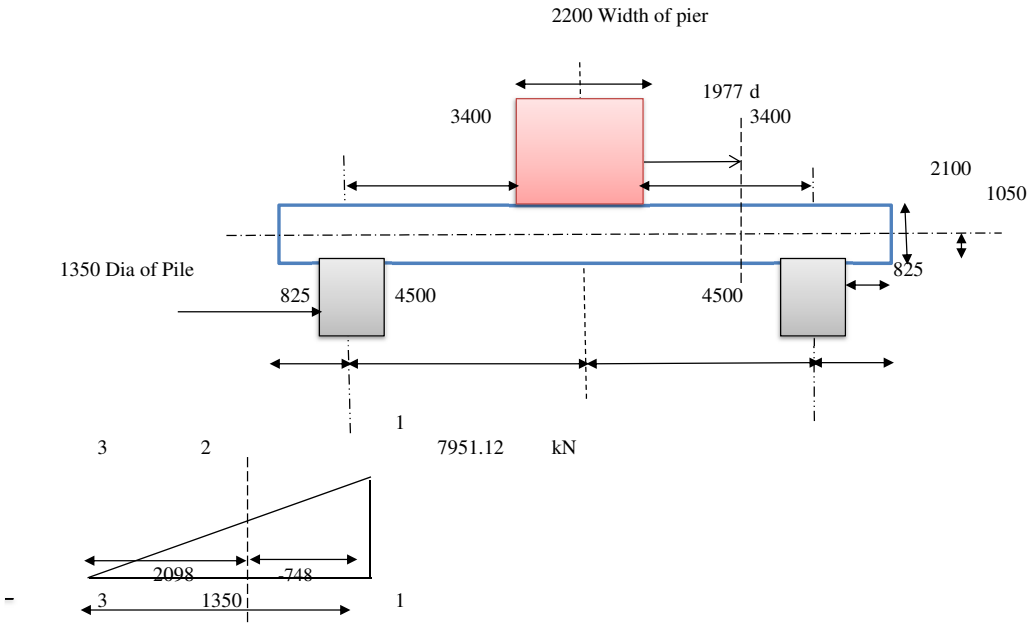
and $v_{min} = 0.031K^{3/2} f_{ck}^{1/2}$, **Eq. 10.3**

σ_{cp} is limited to $0.2 f_{cd}$ (MPa) where $\sigma_{cp} = N_{Ed} / A_c < 0.2 f_{cd}$ (MPa)

$\rho_1 = \frac{A_{sl}}{b_w.d} \leq 0.02$ (Fig.10.5)

K=	1.32		
p_1 =	0.008136042	<	0.20
σ_{cp} =	0.0000	<	3.12
VRD.c =	1803.08	KN	
>	3118.09	KN	

Check for shear in Longitudinal Direction:



Effective depth	=	1977 mm
Critical section for shear = d from face of pier		
	=	1977 mm
Distance from face of Pier to inner face of end of pile		2725.0 mm
Distance from face of Pier to outer face of pile		4075.0 mm

Since the Critical section is inside the end pile edge,Pile Cap to be designed for Shear

S.F at Section 1- 1=	7951.12	kN
S.F at Section 3-3=	0	kN
S.F at Section 2-2=	7951.12	kN

SF At Critical Section (2-2)	=	7951.12 kN	
Dispersion width available	=	2550 mm	
Toatl Design S.F (V)	=	7951.12	kN
Toatl Design S.F (V)/m width	=	3118.09	kN

Check for yielding of steel in shear as per IRC:112-2011, Cl 10.3.3.2

VRDS = VNS = (ASW / S) * z * fywd * cot θ

Where,

ASW = C/S area of shear reinforcement

s = spacing of stirrups

z = Liver arm, for RCC = 0.9 * dpro

fywd = Design yield strength of shear reinforcement = 0.8 * fy

f_{ywd} = 478.50 N/mm^2 (0.87/1.15 fy)

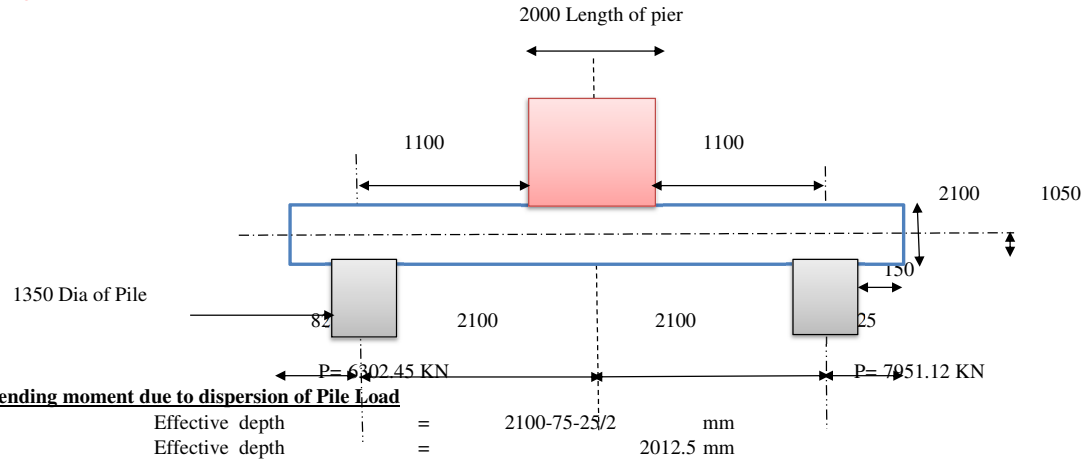
Assuming 5 L Y - 12

Spacing required (s) = (ASW * z * fywd * cot θ / VNS

s = 154.41 mm **=120** mm

Provide **5 - L Y 12 @ 120 mm c/c per m**

Bending Moment in Transverse Direction:



a) Bending moment due to dispersion of Pile Load

Effective depth = 2100-75-25/2 mm

Effective depth = 2012.5 mm

Clear Distance between pile to pile = 750 mm

Hence Dose not over lap

Effective width of dispersion = 150+1350+1050

= 2550 mm

Pile rection = 7951.12 kN

Bending Moment = 7,951.12x1.10= 8746.24 kNm

B.M /meter Width = 3429.90

b) Bending moment due to dispersion of Pier Load

Maximum Axial force for Pier (Factored Combinations) = = 28778.8 KN

Width of dispersion from Pier on pile cap (B_{eff}) = 2000+1050+1050 = 4100 mm

Dispersed Area of Pier = 9.020 m^2

Pier Load per dispersed area of pier (factored) = 3190.55 KN/m^2

Moment due to this load = = 3190.55x1.05X1.05/2 = 1758.8 KNm/m

Resultant Moment due to Pile Load and Pier load = **3429.90 KNm/m**

Design

For M-max = **3429.90 kN-m/m**

Grade of Concrete = **35** Mpa

Grade of steel = **550** Mpa

Clear cover = **75** mm

Dia of main bar = **25 mm**

Effective depth required = $\sqrt{\frac{3430 \times 1000000}{\quad}}$

$$= \sqrt{0.133 \times 35 \times \frac{1000}{1000}}$$

= 858.38 mm

Effective depth provided = 1988 mm > **SAFE**

Ast required = 3717.63 mm^2

As per IRC:112-2011, Cl:16.5.1.1, Pg no 175,

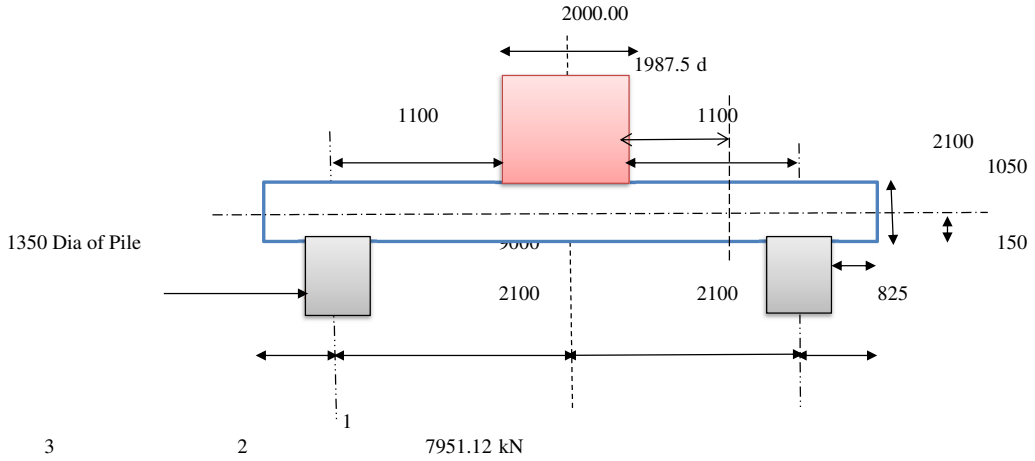
Ast max is not greater than **0.025 Ac** Ast min = 0.0013* b*d = 2570.1 mm2

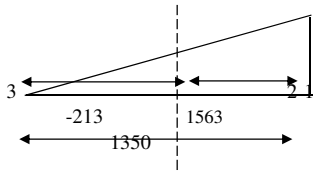
Total Ast + Asc is not greater than **0.04 Ac** Ast min = 0.26*fctm *b.d/fyd = 3025.3 mm2

Hence **Required A_{st}** = **3717.63** mm2

Provide Y - 25 @ 100 C/C $Ast_{Provided}$ = 4908.7 **HENCE O.K**

Check for shear in Transverse Direction:





Clear Distance between pile to pile	=	75 mm	
Effective depth	=	1987.5 mm	
Critical section for shear = d from face of pier			
	=	1987.5 mm	
Distance from face of Pier to inner face of end of pile		425.0 mm	
Distance from face of Pier to outer face of pile		1775.0mm >	1987.5mm

Since the Critical section is beyond pile edge, Shear will not govern the design.

Stress Check calculation for Pile Cap (For Rare Combiantion-Table No 3.3 of IRC6-2014)

(As per IRC 112-2011, Cl:12.3.4)

		Longitudinal	Transverse	
Width of pile beam =	b=	**1000**	**1000**	mm
Thickness of Beam (mm)	h =	2100	2100	mm
Dia of main Bar (mm)		32	25	mm
Effective Depth (deff) mm		1977	2013	mm
Ast pro (mm2)		16084.95	4908.74	mm^2
Max Moment (kN-m)		7523.85	2434.19	N/mm^2
Es (N/mm^2)		200000	200000	N/mm^2
Ec.eff (N/mm^2)		12955	12955	
m = α = Es/Ecm		15.44	15.44	
X_U (mm) =		773.20	481.67	mm
L.A (mm) =		1652.26	1810.20	mm
Stress in Steel (N/mm2)		283.10	273.94	N/mm^2
Permissible stress in steel		440	440	N/mm^2
Check for stree in steel		Hence OK	Hence OK	
Stress in Concrete (N/mm2)		11.78	5.58	N/mm^2
Permissible stress in concrete		13	13	N/mm^2
Check for stree in concrete		Hence OK	Hence OK	

L.A= d - 0.42Xu

Stress in Steel = M/ (Ast xL.A)

Stress in concrete= M/ (0.5.Xu.b.(L.A)

$b X_u^2/2 = m Ast (d-X_u)$

a	500.00	500.00	
b	248311.48	75778.65	
c	-490911802.56	-152504534.98	
Xu 1 =	773.20	481.67	
Xu 2=	-1269.82	-633.23	

Maximum Pile load = 4203 kN C26

Dispersion width due to Pile= 2.550 m

Lever Arm for BM = 1.100 m

Bending Moment due to Pile = 1813.18 kNm

CRACK WIDTH CALCULATION (For Quasi Permanent Combiantion-Table No 3.3 of IRC6-2014)

Dia of main Bar (mm)	32	25
Spacing of Bars (mm)	100	100
Max Moment (kN-m)	5604.37	1813.18
Ast pro As (mm^2)	16084.95	4908.74
C_{min} (mm)	75	75
a_{cr} (mm)	87.83	88.28
h (mm)	2100.00	2100.00
d (mm)	1977.00	2012.50
Es (N/mm^2)	200000	200000

Ec.eff (N/mm^2)		12955	12955
m = α = Es/Ecm		15.44	15.44
Xu (mm)		773.20	481.67
s_{sc} (N/mm^2)		210.88	204.05
k_t =		0.5	0.5
$f_{ct,eff}$ (N/mm^2)		3	3
$A_{c,eff}$ = b*$h_{c,eff}$ (mm^2)		307500.00	218750.00
$h_{c,eff}$ least of	2.5 (h - d)	307.5	218.8
	(h - Xu) / 3	442.3	539.4
	h / 2	1050.0	1050.0
$r_{P,eff}$ =		0.0523	0.0224
e_{sm} - e_{cm} =		0.00080	0.00057
		≥ 0.00063	≥ 0.00061
e_{sm} - e_{cm} =		0.00080	0.00061
IRC 112-2011	k1 =	0.8	0.8
	k2 =	0.5	0.5
Spacing	5(c + dia/2) =	455.00	437.50
Case(i)	$S_{r,max}$ (mm)=	359.00	444.39
Case(ii)	$S_{r,max}$ (mm) =	1724.84	2103.83
$S_{r,max}$ (mm) =		359.00	444.39
W_k (mm) =		0.285	0.272
Check for Crack Width		Hence OK	Hence OK

Ecm = 32000 MPa
Ac = 2100000 mm^2
u= 6200 mm
2Ac/u = 677.4 mm

210.8767602

As per IRC:112-2011, table-6.9, for RH-80%, & 28 days age loading

ø 1= 1.7 for 150
ø 2= 1.5 for 600
ø = **1.47** for 677

Ec,eff = Ecm / (1+ ø)

Ec,eff = **12955.47** MPa

Es = 200000.00 MPa
m = 15.44

Check for Punching Shear

Maximium pile load = 7951.12 kN

Allowable punching shear as per IRC:112-2011, Cl:10.4.5, Pg no 104,

Check For Punching Shear,as per cl. 10.4.3, IRC:112-2011

V_{min} 2d/a = 7.412

K = 1.316 < 2

v_{min} = 0.277 N/mm^2

r_l = 0.00423 < 0.02

v_{Rd} = 11.749 N/mm^2 > 7.41

Punching shear stress $v_{ED} = \dfrac{\beta \times V_{ED}}{u_i \times d}$

β = 1

v = 0.532 N/mm^2

fcd	=	15.63 N/mm^2				
$v_{Rd,max}$	=	4.16 N/mm^2				

a) At the basic control perimeter ui (At Corner Pile)
(2d/2+1000+2d/2)

u_i	=	4374.6 mm	(From Auto Cad)			
v_{ED}	=	0.919 N/mm^2	<	4.16	**SAFE**	

v_{Rdmax}	>	v_{Ed}			
4.16	>	0.919	HENCE	**SAFE**	

5) Design of Pier Pile

The Pile is Designed for Axial Load and BM. The Top fixity is considered at the Bottom of Pile cap and Bottom Fixity is calculated as per Annex C, IS2911- Part1, SEC4 (2010)

Dia of Pile		*1350 mm*		
Grade Of Concrete	*M*	*M35*		
ECONCRETE	*Fe*	*32000.00 MN/m2*	(As per IRC 112-2011,Table 6.5)	
M.I)Pile		*0.163065197 m4*		

T= $5\sqrt{(EI/\eta_h)}$

R= $4\sqrt{(EI/KB)}$

From Table - 5, η_h = (for Medium Sand) *2.840 MN/m3 (Conservatively)*

Corresponding to N value of 20

Table 5 Modulus of Subgrade Reaction for Granular Soils, η_h, in kN/m^3
(Clauses C-2.1 and C-2.3.1)

Sl No.	Soil Type	N (Blows/ 30 cm)	Range of η_h kN/m^3 × 10^3 Dry	Submerged
(1)	(2)	(3)	(4)	(5)
i)	Very loose sand	0-4	< 0.4	< 0.2
ii)	Loose sand	4-10	0.4-2.5	0.2-1.4
iii)	Medium sand	10-35	2.5-7.5	1.4-5.0
iv)	Dense sand	> 35	7.5-20.0	5.0-12.0

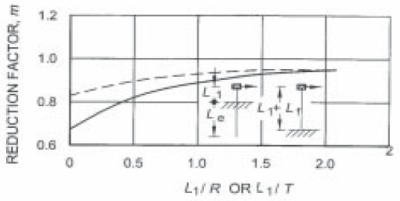
NOTE — The η_h values may be interpolated for intermediate standard penetration values, *N*.

C-2.3.1 *For Piles in Sand and Normally Loaded Clays*

Stiffness factor *T*, in m = $\sqrt[5]{\frac{EI}{\eta_h}}$

η_h = modulus of subgrade reaction, in MN/m^3 (*see* Table 5).

Top Fixity Level(Bottom Of Pile Cap)			*895.125 m*			
	L1=		*0.000 m*			
Calculating,						
T=	*4.50 m*		*4.50 m*			
	L1/T=		*0.00 m*			
From Fig 4 (IS 2911-SeC 4,2010)		*LF/T =*	*2.20*			
Hence, LF =			*9.89 m*			
Lever Arm =		*Top Fixity*	-	*Scour Level*	+	*Lf*
		895.125	-	*895.125*	+	*9.891*
		L.A =	*9.9 m*			
BM in Pile =	*HX9.89/2=*	=				
Redution Factor	=	*0.85*	*From Fig 5 (IS 2911-SeC 4,2010)*			
Final L.A	=	*8.41 m*				
Self Weight of the Pile =	=	*262.062 kN*				



5B For Fixed Head Pile

i) Normal & Wind combinations (Factored Loads)

Load Case	*P(kN)*	*HL/Pile (kN)*	*HT/Pile(kN)*	*H=√HL^2+HT^2*	*BM(kNm)*	*Remarks*
C2	3380.0	*278.56*	*33.10*	*280.52*	*1203.99*	*Normal Comb*
C4	3213.9	*297.29*	*33.10*	*299.13*	*1282.22*	*Normal Comb*
C8	3416.9	*270.85*	*33.10*	*272.86*	*1171.80*	*Normal Comb*
C10	3208.4	*291.09*	*33.10*	*292.97*	*1256.33*	*Normal Comb*
C14	3653.2	*221.01*	*55.17*	*227.79*	*982.33*	*Wind Comb*
C16	3516.8	*235.37*	*55.17*	*241.75*	*1041.01*	*Wind Comb*
C20	3600.2	*215.10*	*55.17*	*222.06*	*958.24*	*Wind Comb*
C22	3440.4	*230.62*	*55.17*	*237.13*	*1021.58*	*Wind Comb*
C25	5025.3	*13.79*	*55.17*	*56.87*	*263.79*	*Wind Comb*
C26	3413.8	*31.71*	*0.00*	*31.71*	*158.03*	

	P(kN)	*BM(kNm)*	*Pu / fck * D * D*	*Mu / fck * D * D * D*	*As per SP:16 p/fck*	*Asc = p*(area of pier)*	*Combination*
Max P Case	5025.3	*263.79*	0.079	0.003	*0.010*	***5009.86***	C25
Max BM Case	3213.9	*1282.22*	0.050	0.015	*0.010*	***5009.86***	C4
Min P Case	2836.8	*1177.79*	0.044	0.014	*0.010*	***5009.86***	C9

ii) Seismic combinations (Factored Loads)

Load Case	*P(kN)*	HL/Pile (kN)	*HT/Pile(kN)*	*H=√HL^2+HT^2*	BM(kNm)	*Remarks*
C1	3860.9	*151.43*	*14.90*	*152.16*	*664.38*	*Seismic*
C3	3068.5	*231.75*	*50.63*	*237.22*	*1021.95*	*Seismic*
C5	3035.1	*235.50*	*50.53*	*240.86*	*1037.27*	*Seismic*
C9	3052.2	*237.34*	*50.63*	*242.68*	*1044.94*	*Seismic*
C11	3003.4	*241.14*	*50.53*	*246.38*	*1060.47*	*Seismic*

	P(kN)	*BM(kNm)*	*Pu / fck * D * D*	*Mu / fck * D * D * D*	*As per SP:16 p/fck*	*Asc = p*(area of pier)*	*Combination*
Max P Case	3860.9	*664.38*	*0.061*	0.008	*0.0100*	***5009.86***	C1
Max BM Case	3003.4	*1060.47*	*0.047*	0.012	*0.0100*	***5009.86***	C11
Min P Case	2934.7	*1034.10*	*0.046*	0.012	*0.0100*	***5009.86***	C12

iii) Stress Check for Pile Loads Rare combination-Table No B.3 of IRC6-2016

Normal & Wind combinations

Check For Stresses : The Pile is Checked for Combined Axial and Bending using in house Computer programme The Stress Calculation is done for both Maximum reaction & BM and Minimum Reaction & BM Finding the Area of steel for Piles, for factored load combination

Load Case	**P(kN)**	**HL/Pile (kN)**	**HT/Pile(kN)**	**H=√HL^2+HT^2**	**BM(kNm)**	*Remarks*
C2	*2595.41*	*185.70*	*22.07*	*187.01*	*786.2*	*Normal Comb*
C4	*2484.62*	*198.19*	*22.07*	*199.42*	*838.3*	*Normal Comb*
C8	*2619.97*	*180.56*	*22.07*	*181.91*	*764.7*	*Normal Comb*

C10	2481.00	194.06	22.07	195.31	821.1	Normal Comb
C14	2739.31	144.34	36.78	148.95	626.2	Wind Comb
C16	2656.22	153.70	36.78	158.04	664.4	Wind Comb
C20	2758.62	140.48	36.78	145.21	610.5	Wind Comb
C22	2654.59	150.60	36.78	155.03	651.7	Wind Comb
C25	3992.87	9.19	36.78	37.91	159.4	Wind Comb
C26	2528.77	31.71	0.00	31.71	133.3	

	P(kN)	BM(kNm)	Pt	Stress in Conc (N/mm2)	Stress in Steel (N/mm2)	Permissible Stress in Concrete	Permissible Stress in Steel	Combinations
Max P Case	3992.9	159.38	0.42	5.62	18.83	16.8	440	C25
Max BM Case	2484.6	838.33	0.42	8.20	114.72	16.8	440	C12
Min P Case	2233.3	768.71	0.42	7.52	127.39	16.8	440	#N/A

As per IRC:112-2011, table-6.9, for RH-80%, & 28 days age loading

ø 1= 1.7 for 150

ø 2= 1.5 for 600

ø = **1.47** for 675

Ec,eff = Ecm / (1+ ø)

Ecm = 32000 MPa

Ac = 1431388.153 mm^2

u= 4241.150082 mm

2Ac/u = 675 mm

Ec,eff = **12955.47** MPa

Es = 200000.00 MPa

m = 15.44

Design of Reinforcement:

Dia of Pile = *1350 mm*

Clear cover = *75 mm*

Dia of Tie = *8 mm*

*core dia = Dia of pier - 2*clear cover* = *1200 mm*

Grade of Concrete = *M - 35 mm*

Grade of Steel = *Fe - 550 N/mm2*

N/mm2

As per IRC:112-2011, The minimum Ast for Compression member is as follows,

1). (Length / radius of gyration) < 12 is "Pedestrian Column"

2). (Length / radius of gyration) > 12 is "Other Column"

Radius of Gyration (Rg) = Sqrt(I/A)

I= 1.63044E+11 mm4

Rg = 338

A = 1431388.153 mm2

Length of pier (L) = 9891

L / Rg = 29 *HENCE IT IS 'OTHER COLUMN'*

Design of Vertical reinforcement

d' = *95.00*

d' / D = *0.07*

refer Chart 56 of SP : 16

p / fck = *0.010*

p = *0.35*

Asc = p(area of pier)/100* = *5009.86 mm2*

0.15% of C/A = 2147.08 mm2

Minimum Ast required = (0.10N/fyd) or 0.002 C/A

0.10N/fyd = 1050.74 mm2

1050.74 mm2

0.002 C/A = 2862.78 mm2

or 2862.78 mm2

There fore Ast min = 2862.78 mm2

However, For Piles, Minimum Pt = 0.4% *Ast= 5725.55 mm2*

Asc Required = *6011.83 mm^2* *Pt = 0.42* *6011.83 (from rare Combination)*

Provide *Y- 20 of* *20 Nos* *6283.19 mm²* *Hence OK* Pt Provided = *0.439*

Lateral ties

As per IRC:112-2011, Cl:16.2.3,
Dia of lateral tie is max of below,

i). *8 mm*
ii). *One quarter of max dia of longitudinal bars* *5 mm*

Hence provide *8 mm*
Spacing of lateral tie is min of belo,
i). *12 times min dia of longitudinal bars* *240.00 mm*
ii). *The least dimension of the column* *954.59 mm*
iii). *200 mm* *200.00 mm*
Hence provide *150 mm*
Hence provide *Y - 8 @* *150 c/c*

1	*Pile Size =*	*1350 mm*	
2	*Grade of concrete =*	*M - 35*	
3	*Grade of steel =*	*Fe - 550*	
4	*main reinforcement =*	*Y- 20 of 20 Nos*	*6283.19 mm²*
5	*Lateral Ties =*	*Y - 8 @ 150 c/c*	

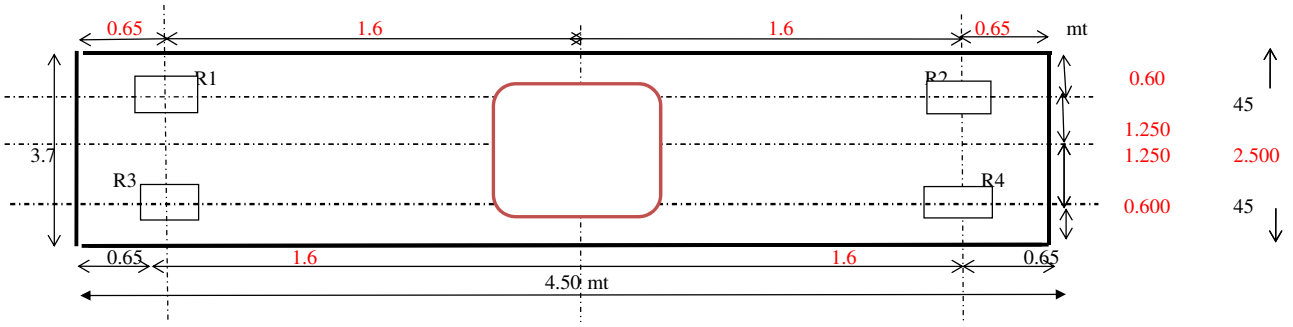
Preliminary Design of Single pier with open foundation supporting 8.5m deck.

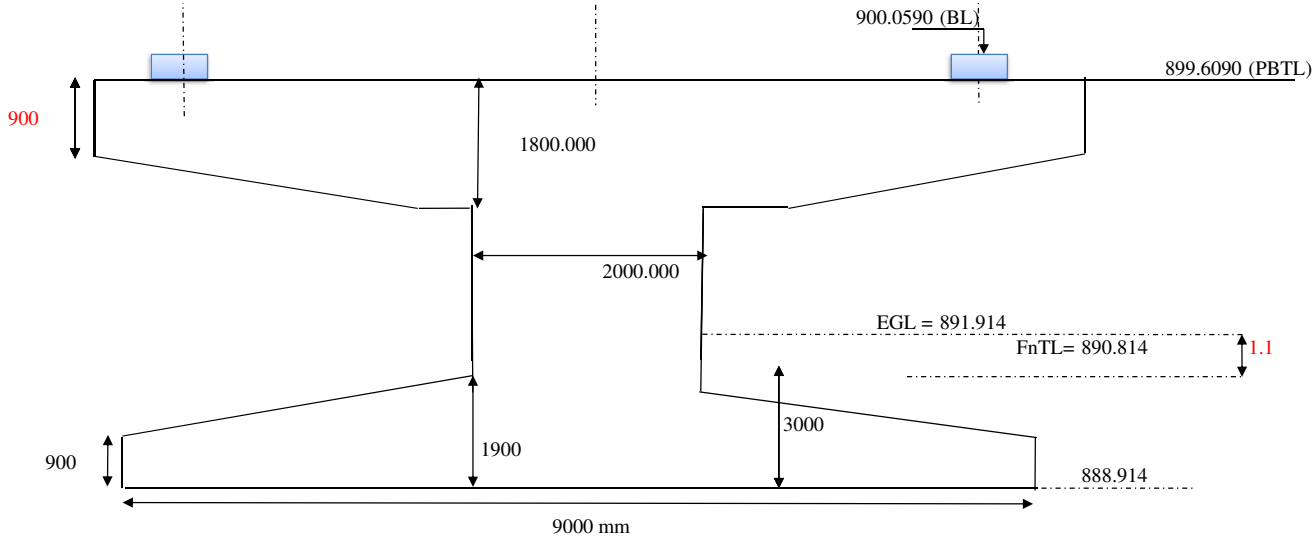
Design of Pier Substructure and Foundation for Piers between 45m and 45m Spans

The Substructure is proposed with single Rectangular Pier with Pier Cap.The Foundation is Open Foundation.The PTFE bearings are proposed on Pier Cap.
Pier Sustructure is analysed for load combinations as per IRC 6-2017 and Designed following IRC 112-2020 codal provisions
This Design note presents design of Pier substructure and foundation for piers supporting 45m+45m spans.

SCHEDULE OF LEVELS

Sl.No	PIER	FRL at edge of Median	EGL	Cross Slope	Superstructure depth +Wearing Coat	PBTL	Foundation top Level	Total height of Pier (m)
1	**P2**	**902.540**	**891.914**	2.50%	2.481	**899.6003**	**890.814**	11.7260





1) GENERAL DATA FOR DESIGN

Finished Road Level	*FRL*	=	***902.540***	m	
Existing ground level	*EGL*	=	***891.914***	m	
Pier Bottom level	*FnTL*	=	***890.814***	m	
Found^{n} Bottom Level	*FnBL*	=	***888.914***	m	
Bearing Level	BL	=	***900.059***	m	
Height of super structure at centre of median (LEFT Span)	45.00 m span	SSD =	***2.431***	m	(Excluding wearing coat)
Height of Super Structure at centre of median (RIGHT Span)	45.00 m span	SSD =	***2.431***	m	(Excluding wearing coat)

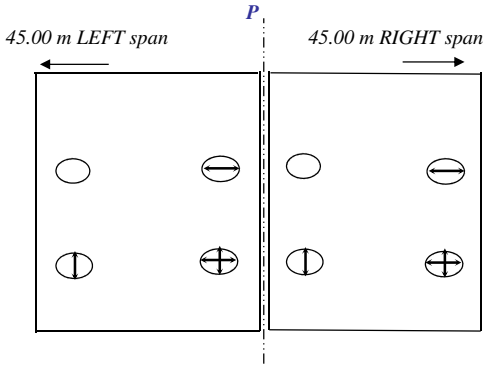
DATA FOR PIER DESIGN

Overall Span of the Bridge (Left Span)	*45.00 m span*	=	*45000*	*mm*	
Effective Span of the Bridge (Left Span)	*45.00 m span*	=	*42500*	*mm*	
Overall Span of the Bridge (Right Span)	*45.00 m span*	=	*45000*	*mm*	
Effective Span of the Bridge (Right Span)	*45.00 m span*	=	*42500*	*mm*	
Overall Width of Deck		=	*8500*	*mm*	
Width of Medain		=	*1000*	*mm*	
Overall Heigth of Substructure (From Bearing Level to Footing Top Level) =			***9245.000***	*mm*	
Width of pier at top (long)		=	2500	*mm*	
Length of pier at top (trans)			2000	*mm*	
Pier Cap Width in Long Dir^{n}.		=	***3700.000***	*mm*	
Pier Cap Length in Trans Dir^{n}.		=	***4500.000***	*mm*	
Straight Depth of Pier Cap		=	***1800.0***	*mm*	PTFE Bearing

Size of bearing for (LEFT Span)	45.00 m span	=	**600**	**x 600**	**x 150**	**2**	*Nos*
Size of bearing for (RIGHT Span)	45.00 m span	=	**600**	**x 600**	**x 150**	**2**	*Nos*
Size of Pedestals for (LEFT span)	45.00 m span	=	**900**	**x 900**	**x 300**	**2**	*Nos*
Size of Pedestals for (RIGHT span)	45.00 m span	=	**900**	**x 900**	**x 300**	**2**	*Nos*

Total straight Height of Pier (From Pier Cap bottom to Pier Bottom Level) =		**6995**	*mm*
Width Of foundation	=	**9000**	*mm*
Length of foundation	=	**10000**	*mm*
Terminated level is considered below EGL =	=	**3000**	*mm*
Footing Bottom Level	=	**888.914**	*m*
Thickness of foundatin at face of peir	=	**1900**	*mm*
Thickness of foundatin at egde	=	**900**	*mm*
Thickness of Wearing coat	=	**50**	*mm*

(Max.Height)



Constants

Density of concrete	=	**25**	kN/m^3
Weight of wearing coat	=	**2**	kN/m^2
Grade of Concrete for Pier Cap,Pier	=	**M - 50**	*MPa.*
Grade of Concrete for Substructure	=	**M - 35**	*MPa.*
Grade of Steel (substructure)	=	**Fe - 550**	*MPa.*

AS PER IRC6:2017, TABLE B.2, PAGE NO 93, THE LOAD FACTORS IS AS UNDER

For Verification of Structural Strength

Sl Nos	*Loads*	*VLL is Leading & Wind is accompanying*	*Wind is Leading & VLL is accompanying*	*Seismic is Leading & VLL is accompanying*
1)	*SW =*	**1.35**	1.35	1.35
2)	*SIDL(W/o WC) =*	**1.35**	1.35	1.35
3)	*WC =*	**1.75**	1.75	1.75
4)	*VLL =*	**1.50**	1.15	0.2
5)	*BRAKING FORCE =*	**1.50**	*1.15*	0.2
6)	*WIND =*	**0.90**	*1.5*	-
7)	*Seismic =*	-	-	1.5

B.1) DEAD LOAD FROM SUPERSTRUCTURE(From STAAD)

Left Span 45,m ***Unfactored Loads***

	R1	*R2*
Self Weight	1319.10	1319.10
Crash Barrier+Median	179.70	179.70
WC	168.54	168.54
Total	***1667.34***	***1667.34***

Right Span- 45 m ***Unfactored Loads***

	R3	*R4*
DL	1319.10	1319.10
SIDL	179.70	179.70
WC	168.54	168.54
Total	***1667.34***	***1667.34***

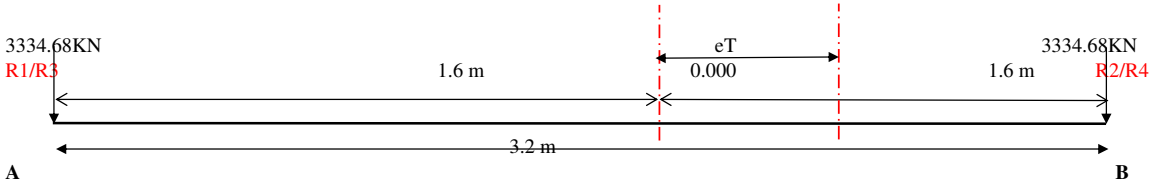
RESULTS FROM STAAD- 45.00 m LEFT span *Factored Loads*

	R1	R2
Self Weight	1780.79	1780.79
Crash Barrier+Median	242.60	242.60
WC	294.95	294.95
FPLL	0.00	0.00
TOTAL	**2318.33**	**2318.33**

RESULTS FROM STAAD- 45 m RIGHT span *Factored Loads*

	R3	R4
DL	1780.79	1780.79
SIDL	242.60	242.60
WC	294.95	294.95
FPLL	0.00	0.00
TOTAL	**2318.33**	**2318.33**

Cakculation of Transverse Moment due to Dead load



Cg of Loads from A = 1.600 m
Cg of Loads from B = 1.600 m
Eccentricity eT= 0.000 m
MT= 0.00 KNm (Unfactored)
MT= 0.00 KNm (Factored)

Calcluation of Moment due to DL in Longitudinal Direction

45 m Right Span e_L = 1.250 m

45 m Left Span e_L = 1.250 m

Factored Longitudinal moment due dead load $M_{L\ (Factored)}$ = 5795.8 - 5795.81
= 0.0 kN-m

ML For Pier Cap Design= 0.00 (Factored) ML For Pier Cap Design= 0.00 (Unfactored)
ML For Pier Design 0.00 (Factored) ML For Pier Design 0.00 (Unfactored)

B.2) LIVE LOAD FROM SUPERSTRUCTURE

Following Vehicular Live loads are considered-

(i). 2 Class A vehicle
(ii). One 70RL Vehicle
(iii). One 70RN Vehicle

The variations of Live load combination is considered as per Table 2 of IRC 6-2017.
The reduction of longitudinal effect is considered as Cl:205 of IRC 6-2017

For 3 lanes Reduction in longitudinal effect = 10

Impact Factor : As per Cl 208 IRC : 6-2017
1) For Class A Vehicle,
2) For 70R Wheeled Vehicle

For 45.00m LEFT span	**L = 42.50 m**		For 45.00 m RIGHT span	**L = 42.50 m**	
L= Effective	= 9.28%	(Cl:208.2)	IF=4.5/(6+L)	= 9.28%	(Cl:208.2)
Span	= 9.28%	(Cl:208.2)	L= Effective Spa	= 9.28%	(Cl:208.2)

a) Vehicular Live Load from Staad pro.for 45.00 m LEFT Span (With impact Factor)

Eccentricity in longitudinal direction = 1.25 mt
For Four lanes 10 percent Reduction

Sl No	Vehicle case	R1(kN)	R2(kN)	R1(kN) Lane Reduction	R2(kN) Lane Reduction	Total reaction (kN)(Lane Reduction)	eL (mt)	ML (kNm)	eT (mt)	MT (kNm)
1	2CA	735.80	423.80	662.22	381.42	**1043.64**	1.250	1304.55	0.430	449.28
2	70R	814.30	126.50	732.87	113.85	**846.72**	1.250	1058.40	1.170	990.43

b) Vehicular Live Load from Staad pro.for 45.00 m RIGHT Span (With impact Factor)

Summary of Reactions For Three Lanes: (From STADD Analysis)
For three lanes 10 percent Reduction
Eccentricity in longitudinal direction = 1.250 mt

Sl No	Vehicle case	R6(kN)	R7(kN)	R6(kN) Lane Reduction	R7(kN) Lane Reduction	Total reaction (kN)(Lane Reduction)	eL (mt)	ML (kNm)	eT (mt)	MT (kNm)
1	2CA	735.20	423.30	661.68	380.97	**1042.65**	1.250	1303.31	0.431	449.14
2	70R	813.60	127.20	732.24	114.48	**846.72**	1.250	1058.40	1.167	988.42

c) Vehicular Live Load from Staad pro.for 45.00 m LEFT Span (Without impact Factor)

Eccentricity in longitudinal direction = 1.25 mt

Sl No	Vehicle case	R1(kN)	R2(kN)	R1(kN) Lane Reduction	R2(kN) Lane Reduction	Total reaction (kN)(Lane Reduction)	eL (mt)	ML (kNm)	eT (mt)	MT (kNm)
1	2CA	673.33	387.82	673.33	387.82	**1061.14**	1.250	1326.43	0.43	456.82
2	70R	745.16	115.76	670.65	104.18	**774.83**	1.250	968.54	1.17	906.34

d) Vehicular Live Load from Staad pro.for 45.00 m LEFT Span (Without impact Factor)

Sl No	Vehicle case	R6(kN)	R7(kN)	R6(kN) Lane Reduction	R7(kN) Lane Reduction	Total reaction (kN)(Lane Reduction)	eL (mt)	ML (kNm)	eT (mt)	MT (kNm)
1	2CA	672.78	387.36	672.78	387.36	**1060.14**	1.250	1325.17	0.43	456.67
2	70R	744.52	116.40	670.07	104.76	**774.83**	1.250	968.54	1.17	904.49

e) Vehicle on Both spans;
Summary of Reactions (From STADD Analysis)

Sl No	Vehicle case	R1(kN)	R2(kN)	R3(kN)	R4(kN)	R1(kN) Lane Reduction	R2(kN) Lane Reduction	R3(kN) Lane Reduction	R4(kN) Lane Reduction
1	2CA	194.78	76.22	200.67	78.53	175.30	68.60	180.60	70.68
2	70R	452.47	73.10	443.54	71.65	407.22	65.79	399.19	64.49

Total reaction (kN)(Lane Reduction)	eL (mt)	ML (kNm)	eT (mt)	MT (kNm)
495.18	1.250	9.22	0.70	346.61
936.68	1.250	11.68	1.15	1081.81

f) Vehicle on Both span(Without impact Factor);

Sl No	Vehicle case	R1(kN)	R2(kN)	R3(kN)	R4(kN)	R1(kN) Lane Reduction	R2(kN) Lane Reduction	R3(kN) Lane Reduction	R4(kN) Lane Reduction
1	2CA	178.24	69.75	183.63	71.86	178.24	69.75	183.63	71.86
2	70R	414.05	66.89	405.88	65.57	372.65	60.20	365.29	59.01

Total reaction (kN)(Lane Reduction)	eL (mt)	ML (kNm)	eT (mt)	MT (kNm)
503.48	1.250	629.36	0.70	352.42
857.15	1.250	1071.44	1.15	989.96

B.3 Braking Force (As per cl 211.2, IRC: 6- 2017)

Braking force is acts at 1.2 mt above road level

ML= HL x L.A

L.A = Lever Arm

Effective span (L) = 42.50 m

FRL = 902.540 m

1) For 45.00m LEFT span

Wearing coat = 0.05 m

Depth of super structure= 2.431 m

L.A = 2.481 + 1.2 = 3.68 m

Sl No	Vehicle case	1st,2nd and 3^{rd}LANE in kN	3rd LANE in kN =	1st & 2nd LANE(20%) in kN	3rd LANE(10%) in kN	Total HL in kN	ML=HL x L.A in kNm
1	2CA	1108.000	1108.000	221.600	110.800	332.400	1223.564
2	70R	1000.000	0.000	200.000	0.000	200.000	736.200

Add Axial load(kN)	Add Axial	HL (kN) per	HL (kN) per
28.790	14.395	166.200	83.10
17.322	8.661	100.000	50.00

2) For 45.00 m RIGHT span

Wearing coat = 0.05 m Effective span (L) = 42.5 m

Depth of super structure= 2.431 m FRL = 902.540 m

L.A = 2.481 + 1.2 = 3.68 m

Sl No	Vehicle case	1st & 2nd LANE in kN	3rd LANE in kN	1st & 2nd LANE(20%) in kN	3rd LANE(5%) in kN	Total HL in kN	ML=HL x L.A in kNm
1	2CA	1108	1108.00	221.60	110.80	332.40	1223.56
2	70R	1000	0.00	200.00	0.00	200.00	736.20

Add Axial load(kN)	Add Axial	HL (kN) per	HL (kN) per
28.79	14.39	166.20	83.10
17.32	8.66	100.00	50.00

Specimen calculations:

Additional axial load at bearing level= 332.4x(2.481+1.2)/42.5 28.790 kN

B.4 Friction Force (Normal Case): As per Cl.211.5.1.1 IRC:6-2017

Fixed Bearings : Fh - μ (Rg + Rq) or (Fh/2) + μ (Rg + Rq)

Fh = Applied Horizontal Force Due to Braking Effect

μ = Co-efficent Friction 0.05 For Surface between PTFE and Steel

Rg = Reaction @ Free End due to Dead load

Rq = Reaction @ Free End due to Live load

Free Bearings : μ(Rg+Rq)

μ = Co-efficent Friction 0.05

Rg = Reaction @ Free End due to Dead load

Rq = Reaction @ Free End due to Live load

For 45.00m LEFT span (one Span loaded case) (With impact Factor): Horizontal Force @ Bearing Level

Sl No	Vehicle case	Fh	μ	Rg / one side of span	Rq (one side of span)	μ (Rg + Rq) @ Free Bearing	μ (Rg + Rq) per Bearing	μ (Rg) per Bearing
1	2CA	0.00	0.05	3334.68	1043.64	218.92	109.4580	83.367
2	70R	0.00	0.05	3334.68	846.72	209.07	104.5350	83.367
						218.92		

For 45.00 m RIGHT span (one Span loaded case) (With impact Factor): Horizontal Force @ Bearing Level

Sl No	Vehicle case	Fh	μ	Rg	Rq	F_h+μ (Rg + Rq) @ Fixed Bearing	F_h+ μ (Rg + Rq) per Bearing
1	2CA	332.400	0.050	3334.680	1042.650	551.27	275.633
2	70R	200.000	0.050	3334.680	846.720	409.07	204.535

B.6 Wind load calculation as per IRC 6:2017 Cl:209

Wind Speed at the Project Site 33 m/s

Avg Ht of the deck above EGL 11.626 m (ht of superstr+1m Crash barrier)

Type of Terrain — Since the Grade separator is inside the city with well developed Buildings.

	Terrain with Obstructions	
	Height	Pz
Upto	10	0.1905
	15	0.2305
	20	0.2650
	11.626 m	0.203

Pressure as per table 0.203 kN/sqm FRL 902.540

Pressure as per table, corresponds to basic wind speed of 33 m/s

Design wind pressure =(wind speed at site^2/33^2) x Wind pressure corresponding to 33 m/sec

Deisgn wind pressure = 0.2026137x(33^2/33^2= 0.203 kN/sqm

Design Pressure Pz= **0.203** kN/sqm GL 891.914

Wind Force in Transverse direction = Pz X A1 X G X Cd

G = gust factor = 2.00

Cd = drag coeff =

1.1 for Slab bridges with b/d>10
1.5 for Box/single beam b/d 2
1.3 for Box/single beam b/d> 6
2.25 for 2 or more Box/ beam b/d 2
1.95 for 2 or more Box/ beam b/d > 6
2.20 for single plate girder
2(1+c/20d) for multiple plate girders

C= Centre to centre distance of adjacent girders = 1.60 m d =

Cd =	1.425

Wind on Superstructure :

For 45.00m LEFT span

Wind Force in Transverse direction = Pz X A1 X G X Cd

Length of span from Centre to centre of Expansion Joint = 45 m

Effective Span = 42.5 m

Width of Deck = 8.5 m

Superstructure Depth 2.481 m

Total depth =(Superstucture Depth + Crash barrier height (1m)) SSD= 2.481 m, CBD= 1.00m 3.481 m

Area of Superstructure 3.481 x 45.000 **156.645**

Force in Transverse direction = Pz X A1 X G X Cd

FT = 0.203x156.645x2x1.425 **90.45** m^2

MT Bearing Level due to 45.00 m span

L.A = 3.481 /2 = 1.741 m

MT Bearing Level due to 45.00 m span **= 157 KNm**

MT Bearing Level / span **= 79 KNm**

Add^n axial load = MT/(Eff.Bearing Spacing	**78.72/3.2**	**24.599**	kN
Horizontal Force @ Bearing level per span	=	**45.227**	kN
Force in long dir^n = 0.25 times FT	=	**22.614**	kN
Add^n axial load = **22.62/42.5**	=	**0.5**	kN

For 45.00 m RIGHT span

Wind Force in Transverse direction = Pz X A1 X G X Cd

Length of span from Centre to centre of Expansion Joint = 45 m

Effective Span = L = 42.50 m

Width of Deck = 8.5 m

Superstructure Depth 2.481 m

Total depth SSD = 2.481 m, CBD= 1.000 m 3.481 m

Area of Superstructure = 3.481 x 45.000 **156.645**

Force in Transverse direction = Pz X A1 X G X Cd

FT = 0.203x45x2x1.425 **90.45** m^2

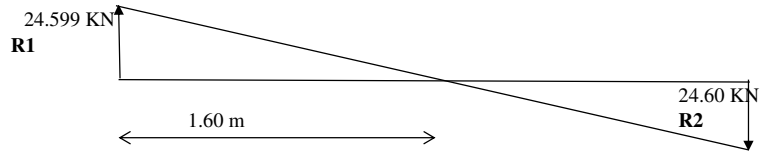
MT Bearing Level due to 45.00 m span

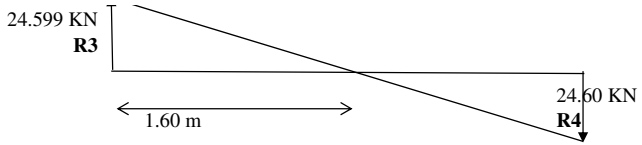
L.A = 3.481 /2 = 1.741 m

MT Bearing Level due to 45.00 m span **= 157 KNm**

MT Bearing Level / span **= 79 KNm**

Add^n axial load = MT/(Eff.Bearing Spacing) =	**78.72/3.2**	**24.599**	kN
Horizontal Force @ Bearing level per span=		**45.227**	kN
Force in long dir^n = 0.25 times FT	=	**22.614**	kN
Add^n axial load = **22.62/42.5**	=	**0.53**	kN





Wind Force on Vertical (+/-) **For 45.00 m span**

Fv = Pz X A3 X G X CL (As per IRC 6-2017,Cl:209.3.5)

A_3 = Area of Superstructure (plan area) 45.0 x 8.5

A_3 = **382.500** m^2

CL = lift coeff = 0.750 for Slab/ box/ I girders and plate girders

Fv = 0.203x382.5x2x0.75 = **= 116.2KN**

Fv/ one side = = **= 58.1KN**

Vertical Force per Bearing = 58.125 / 2 = **= 29.1KN**

Wind Force on Vertical (+/-) **For 45.00 m span**

Fv = Pz X A3 X G X CL (As per IRC 6-2017,Cl:209.3.5)

A_3 = Superstructure (plan area) 45.0 x 8.5

A_3 = **382.5** m^2

CL = lift coeff = 0.750

Fv = 0.203x382.5x2x0.75 = **= 116.2KN** KN

Fv/ one side = **= 58.1KN**

Vertical Force per Bearing = 58.12 / 2 = **= 29.1KN**

Wind on Live Load :

For 45.00m LEFT span

Force in Transverse direction = Pz X A1 X G X Cd

Ht of super structure +Crash Barrier = 3.481 m

Ht of vehicle considerded above Crash barrier= =3-1 2.0 m

Area of Superstructure 2 x 45.0 **= 90.0m2**

Cd = 1.2

L.A = 2.000 /2 + 3.481 = 4.481 m

FT = 0.203x90x2x1.2 = **43.76KN**

MT Bearing Level due to 45.00 m span **43.76KN**

L.A = 4.481 m

MT Bearing Level due to 45.00 m span

MT= 43.765 x 4.481 **= 196 KNm**

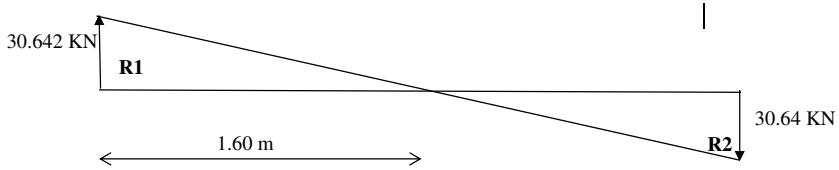
MT Bearing Level / span **= 98 KNm**

Add^n axial load = MT/(Eff.Bearing Spacing) = **98.06/3.2** **= 30.6KN**

Horizontal Force @ Bearing level per span = **= 21.9KN**

Force in long dir^n = 0.25 times FT **= 10.9KN**

Add^n axial load = **0.25x98.06/42.5** **= 0.6KN**



For 45.00 m RIGHT span

Force in Transverse direction = Pz X A1 X G X Cd

Ht of super structure +Crash Barrier = 3.48 m

Ht of vehicle considerded above Crash barrier= 2.0 m

ea of Superstructure A1 = 2 x 45.0 **= 90.0m2**

Cd = 1.2

L.A = 2.000 /2 + 3.481 = 4.481 m

FT = 0.203x90x2x1.2 = **43.76KN**

MT Bearing Level due to 45.00 m span

L.A = 4.481 m

MT Bearing Level due to 45.00 m span

MT= 43.765 x 4.481 **= 196 KNm**

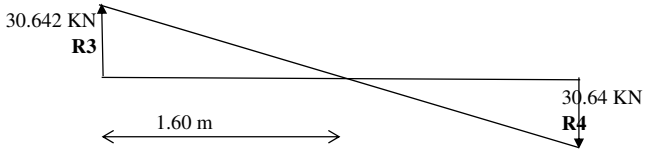
MT Bearing Level / span **= 98 KNm**

Add^n axial load = MT/(Eff.Bearing Spacing) = **98.06/3.2** **= 30.6KN**

Horizontal Force @ Bearing level per span = **= 21.88KN**

Force in long dir^n = 0.25 times FT **= 10.94KN**

Add^n axial load = **0.25x98.06/42.5** **= 0.58KN**



Summary of wind force at bearing level :

Sl No	Load case	HT (kN)	HT / Bearing (kN)	HL (kN)	HL / Bearing (kN)	Vertical Force(kN) / One side of span	Vertical Force(kN) / Bearing
1	Wind on loaded structure from 45.00m span (One side of LEFT span)	67.11	33.55	16.8	8.39	114.5	57.24
2	Wind on Unloaded structure from 45.00m span (One side of LEFT span)	45.23	22.61	11.3	5.65	83.3	41.63
3	Wind on loaded structure from 45.00m span (One side of RIGHT span)	67.11	33.555	16.8	8.389	114.5	57.238
4	Wind on Unloaded structure from 45.00m span (One side of RIGHT span)	45.23	22.614	11.3	5.653	83.3	41.628

DESIGN OF PIER CAP:

Distance from Face of Beam to cg of load — a = 600.00 mm — No of Bearings on Cantilever **45.00 m span** = 1

Thickness of corbel//Pier beam at face — h = 1800.000 mm — Portion of Beam from LEFT

Effective depth of corbel/Pier beam — d' = 1706.500 mm — No of Bearings on Cantilever **45.00 m span** = 1

d = 1365.200 (0.8d') — Portion of Beam from RIGHT

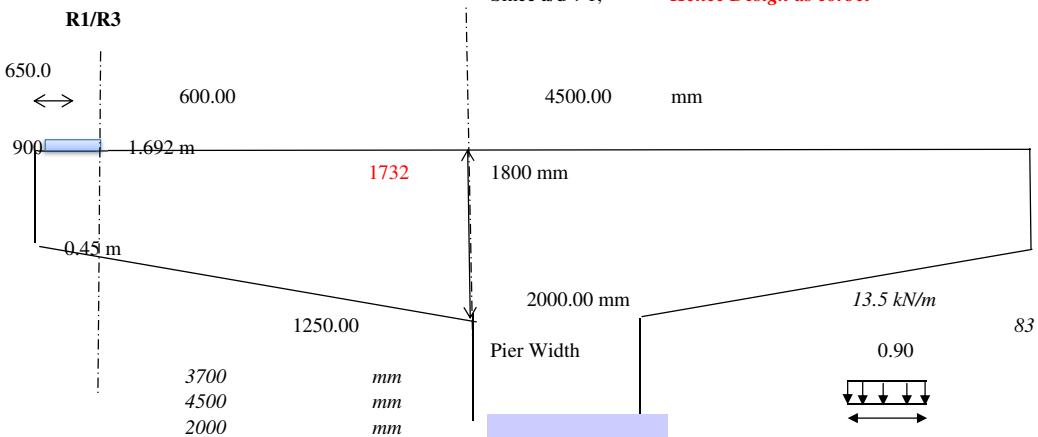
Thickness of Pier beam at end — S = 900.000 mm

Eff. width of beam — b = 3700.000 mm

Checks actual

If a/d' <= 1.0 Design as a Corbel — a/d' = 0.352 — Vu/bd <= 0.15fc — 1.237 < 7.500 **safe**

Since a/d' >1, ***Hence Design as corbel***



Lever Arms w.r.t face of pier	
L.A3=	0.600 m
L.A1=	0.600 m

Pier Beam width = 3700 mm

Total length of Pier beam = 4500 mm

Pier Width = 2000 mm

Summary of Forces on Pier Cap (Pier Beam) **(TABLE No -1)** Pedestal Loading

1) Forces on Pier Cap due to Dead load

Type of Loads		Loads for Factored Combination			Loads for Rare combination			Loads for Frequent combination		
		P (Shear) in kN	*ML (Torsion) in kN-m*	*B.M (MT) in kN-m*	*P in kN*	*ML (Torsion) in kN-m*	*B.M (MT) in kN-m*	*P in kN*	*ML (Torsion) in kN-m*	*B.M (MT) in kN-m*
Dead Load from Superstructure w.r.t to face of Pier	R1	2318.33	0.00	1391.00	1667.34	0.00	1000.40	1667.34	0.00	1000.40
	R3	2318.33	0.00	1391.00	1667.34	0.00	1000.40	1667.34	0.00	1000.40

Dead Load from superstructure w.r.t to face of Pedestal-@ (R1 +R5)	R1+R3	4636.65	0.00	2086.49	3334.68	0.00	1500.61	3334.68	0.00	1500.61

2) Forces on Pier Cap due to Vehicular Live load

Type of Loads		Loads for Factored Combination			Loads for Rare combination			Loads for Frequent combination		
		P (Shear) in kN	ML (Torsion) in kN-m	B.M (MT) in kN-m	P in kN	ML (Torsion) in kN-m	B.M (MT) in kN-m	P in kN	ML (Torsion) in kN-m	B.M (MT) in kN-m
VLL (One Span) w.r.t face of Pier	R1	1099.31	1374.13	*659.58*	732.87	916.09	*439.72*	549.65	687.07	*329.79*
	R3	1098.36	1372.95	*659.02*	732.24	915.30	*439.34*	549.18	686.48	*329.51*
VLL (One Span) w.r.t face of Pedestal@	R1	1099.31	1374.13	494.69	732.87	916.09	329.79	549.65	687.07	*247.34*
VLL (Both Span) w.r.t face of Pier	R1	610.83	15.07	*366.50*	407.22	10.05	*244.33*	305.42	7.53	*183.25*
	R3	598.78	0.00	*359.27*	399.19	0.00	*239.51*	299.39	0.00	*179.63*
VLL (Both Span) w.r.t face of Pedestal-(R1+R5)		1209.61	15.07	544.33	407.22	10.05	183.25	305.42	7.53	137.44

3) Forces on Pier Cap due to Braking Force and Frictional Force

Type of Loads	Loads for Factored Combination			Loads for Rare combination			Loads for Frequent combination		
	P (Shear) in kN	ML (Torsion) in kN-m	B.M (MT) in kN-m	P in kN	ML (Torsion) in kN-m	B.M (MT) in kN-m	P in kN	ML (Torsion) in kN-m	B.M (MT) in kN-m
Braking and Frictional Force at Bearing level (LEFT From 33.4m span)									
Braking force w.r.t face of Pier (R1)	21.59	369.42	12.96	14.39	246.28	8.64	10.80	184.71	6.48
Braking force w.r.t face of Pedestal@ (R1)	21.59	351.69	9.72	14.39	234.46	8.64	10.80	175.84	6.48
Braking and Frictional Force at Bearing level (RIGHT From 33.4m span)									
Braking force w.r.t face of Pier (R3)	21.59	930.26	12.96	14.39	620.17	8.64	10.80	465.13	6.48
Braking force w.r.t face of Pedestal@ (R3)	21.59	657.17	9.72	14.39	438.11	6.48	10.80	328.59	4.86
Centrifugal Force Due to Curvature effect									
Cerntrifugal Force at face of pier	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cerntrifugal Force at face of Pedestal@R1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*0.00*
Cerntrifugal Force w.r.t w.r.t 'd' from face of pier	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*0.00*

4) Force due to Self Weight of Pier Beam and Pedestal

Type of Loads	Loads for Factored Combination			Loads for Rare combination			Loads for Frequent combination		
	P (Shear) in kN	ML (Torsion) in kN-m	B.M (MT) in kN-m	P in kN	ML (Torsion) in kN-m	B.M (MT) in kN-m	P in kN	ML (Torsion) in kN-m	B.M (MT) in kN-m
Force due to Self Weight of Pier Beam									
Pier Beam w.r .t face of Pier	210.73		*117.04*	156.09		*86.70*	156.09		*97.56*
Pier Beam w.r .t face of Pedestal	178.02		*87.92*	131.87	0.00	*65.13*	131.87	0.00	*65.13*

Force due to Self Weight of Pedestal									
Pedestal w.r.t to face of Pier @ (R1+R3)	16.40		9.84	12.15	0.00	7.29	12.15	0.00	7.29
Pedestal w.r.t to face of Pedestal-@ (R1+R3)	16.40		7.38	12.15	0.00	5.47	12.15	0.00	5.47
5) Forces due to Wind on Pier Cap									
Type of Loads	**Loads for Factored Combination**			**Loads for Rare combination**			**Loads for Frequent combination**		
	P (Shear) in kN	***ML (Torsion) in kN-m***	***B.M (MT) in kN-m***	***P in kN***	***ML (Torsion) in kN-m***	***B.M (MT) in kN-m***	***P in kN***	***ML (Torsion) in kN-m***	***B.M (MT) in kN-m***
Wind Forces on Super structure									
Wind on Super Structure w.r.t face of Pier @ (R1+R3)	44.28	81.22	*324.86*	29.52	54.14	*216.58*	24.60	45.12	180.48
Wind on Super Structure w.r.t face of Pedestal-@ (R1+R3)	44.28	79.02	*316.07*	29.52	52.68	*210.71*	24.60	43.90	175.59
Wind Forces on Live Load									
Wind on Live Load w.r.t face of Pier @ (R1+R3)	55.16	66.28	*265.12*	36.77	44.19	176.75	30.64	36.82	147.29
Wind on Live Load w.r.t face of Pedestal-@ (R1+R3)	55.16	65.22	*260.87*	36.77	43.48	173.91	30.64	36.23	144.93
Vertical force due to Wind									
Verticle wind load per Bearing w.r.t face of Pier @ (R1+R3)	52.31	0.00	*31.39*	34.87	0.00	20.92	29.06	0.00	17.44
Verticle wind load per Bearing w.r.t face of Pedestal-@ (R1+R3)	52.31	0.00	23.54	34.87	0.00	15.69	29.06	0.00	13.08

Load Combinations:

Comb:-1 DL+VLL (Braking,Centrifugal,Frictional Force)+Wind Load (VLL One Span Condition)

Comb:-2 DL+VLL (Braking,Centrifugal,Frictional Force)+Wind Load (VLL Both Span Condition)

Summary of Forces **(TABLE No -2)** **(Combination 1)**

Load Combination	**Pier Cap Forces w.r.t face of Pier**			**Pier Cap Forces w.r.t face of Pedestal @ (R1+R5)**		
	P (Shear) in kN	***ML (Torsion) in kN-m***	***B.M in kN-m***	***P (Shear) in kN***	***ML (Torsion) in kN-m***	***B.M in kN-m***
Factored Combination	**6136.4**	**2451.89**	**4202.8**	**6103.7**	**2175.5**	**3286.7**
Rare Combination	**4351.35**	**1634.59**	**2957.40**	**4327.13**	**1450.36**	**2309.95**
Frequent Combination	**4147.68**	**1234.14**	**2787.13**	**4123.45**	**1095.78**	**2158.62**
Quasi Permanent Combination	**3502.92**	**0.00**	**2094.80**	**4831.07**	**0.00**	**2181.79**

Summary of Forces **(TABLE No -3)** **(Combination 2)**

Load Combination	**Pier Cap Forces w.r.t face of Pier**			**Pier Cap Forces w.r.t face of Pedestal @ (R1+R5)**		
	P (Shear) in kN	***ML (Torsion) in kN-m***	***B.M in kN-m***	***P (Shear) in kN***	***ML (Torsion) in kN-m***	***B.M in kN-m***
Factored Combination	**6246.7**	**1462.25**	**4269.0**	**6214.0**	**1168.2**	**3336.3**
Rare Combination	**4424.89**	**728.55**	**3001.53**	**4001.48**	**544.32**	**2163.41**
Frequent Combination	**4202.83**	**554.61**	**2820.22**	**3879.22**	**416.25**	**2048.71**

Quasi Permanent Combination	3502.92	0.00	2094.80	3478.70	0.00	1571.20

1) DESIGN OF PIER CAP

Grade of concrete = M50
Grade of steel = Fe550

$Q = 0.133\ fck$ (for Fe 550)
$Q = 6.65\ N/mm2$

Design Moment = 4268.97 kNm
Effective Depth Reqd "deff" = $\frac{M}{Q \times B}$

deff reqd: = $\sqrt{\frac{4268.97 \times 1000000}{6.65 \times 3700}}$ = 416.53 mm < 1731.50 mm O.K

Clear Cover = 40 mm
Bar Dia = 25 mm

deff provided = 1800 - 40 - 16.0 = 1731.50

Area of steel required (Ast) = (50*fck/fy)*(1-sqrt(1-(4.5*Mu/(fck*b*d^2))))*b*d/100

. ˙ . Ast reqd = 6475.16 mm^2
Ast reqd for launching Girder case = 0.00 mm^2
As1 = 490.9 mm^2
No of bars Reqd: = $\frac{6475.2}{490.9}$ = 13.19 = 18 Nos
Spacing of Bars = $\frac{3700}{18}$ = 205.56 mm

So provide 25 mm dia bars , 206 mm c/c spacing in 1 layer of 18 Nos
Ast Provided 8835.7 mm^2
OR 25 mm dia bars , 411 mm c/c spacing in 2 layers of 9 Nos
OR 25 mm dia bars , 617 mm c/c spacing in 3 layers of 6 Nos

Compression reinforcement 16 mm dia bars , of 18 Nos

Check for Serviceability Limit State

1) Stress Check Calculation As per IRC 112-2020 (Quasi Permanent Combination-Table No B.3 of IRC6-2017)

Width of pier beam =	b=	3700
Thickness of Beam (mm)	h =	1800
Dia of main Bar (mm)		25
Effective Depth (deff) mm		1732
Ast pro (mm2)		8836
Max Moment (kN-m)		2094.80
Es (N/mm^2)		200000
Ecm (N/mm^2)		14403
m = α = Es/Ecm		13.89
X_U (mm) =		307.33
L.A (mm) =		1629.06
Stress in Steel (N/mm2)		145.53
Permissible stress in steel		440
Check for stree in steel		Hence OK
Stress in Concrete (N/mm2)		2.26

(Ref Table No-2 and 3)

L.A= d - Xu/3

Stress in Steel = M/ (Ast xL.A)
Stress in concrete= M/ (0.5.Xu.b.(L.A)

$b X_u^2/2 = m\ Ast\ (d-X_u)$

a 1850.00
b 122690.41
c -212438450
Xu 1 = 307.33
Xu 2= -373.65

Permissible stress in concrete		18
Check for stree in concrete		**Hence OK**

2) Crack Width Calculation As per IRC 112-2020 (Quasi Permanent Combination-Table No B.3 of IRC6-2017)

(As per IRC 112-2020, Cl:12.3.4)

Dia of main Bar (mm)		25
Spacing of Bars (mm)		206
Max Moment (kN-m)		2094.80
Ast pro As (mm^2)		8835.73
C_{min} (mm)		40
a_{cr} (mm)		102.91
h (mm)		1800.00
d (mm)		1731.50
Es (N/mm^2)		200000
Ecm (N/mm^2)		14403
m = α = Es/Ecm		13.89
Xu (mm)		307.33
s_{sc} (N/mm^2)		145.53
k_t =		0.5
$f_{ct,eff}$ (N/mm^2)		3.5
$A_{c,eff}$ = b*$h_{c,eff}$ (mm^2)		633625.00
$h_{c,eff}$ least of	2.5 (h - d)	171.3
	(h - Xu/3)	497.6
	h / 2	900.0
$r_{P,eff}$ =		0.0139
e_{sm} - e_{cm} =		0.0000
		≥ 0.0004
e_{sm} - e_{cm} =		0.0004
IRC 112-2020	k1 =	0.8
	k2 =	0.5
Spacing	5(c + F/2) =	262.50
Case(i)	$S_{r.max}$ (mm)=	440.77
Case(ii)	$S_{r.max}$ (mm) =	1940.47
$S_{r.max}$ (mm) =		440.77
W_k (mm) =		0.192
Check for Crack Width		***Hence OK***

3) Stress Check for Provided Steel (Rare Combination) (As per Table No B.3 of IRC6-2017)

Width of pier beam =		b=	3700
Thickness of Beam (mm)		h =	1800
Dia of main Bar (mm)			25
Effective Depth (deff) mm			1732
Ast pro (mm2)			8836
Max Moment (kN-m)			3001.53
Es (N/mm^2)			200000

L.A= d - Xu/3

Stress in Steel = M/ (Ast xL.A)

Stress in concrete= M/ (0.5.Xu.b.(L.A)

a 1850.00

Ecm (N/mm^2)		14403
m = α = Es/Ecm		13.89
X_U (mm) =		307.33
L.A (mm) =		1629.06
Stress in Steel (N/mm2)		208.53
Permissible stress in steel		440
Check for stree in steel		**Hence OK**
Stress in Concrete (N/mm2)		3.24
Permissible stress in concrete		24
Check for stree in concrete		**Hence OK**

$b X_u^2/2 = m Ast (d-X_u)$

b	122690.41
c	-212438450
Xu 1 =	307.33
Xu 2=	-373.65

4) Deflection Check (By Freqent Combination-Table No B.3 of IRC6-2017)

For Cantiliver Slab *Deflection = $P*l^3 / 3EI$*

I = M.I = $bD^3/12$ = *1.7982E+12* mm2

Ec,eff = Ecm / (1+ ø)

Ecm = 35000 MPa (as per IRC-112, table-6.5) (Ref Table No-2 and 3)

P = 4202.83 *KN*

L = 0.60 *m*

As per IRC:112-2020, table-6.9, for RH-80%, & 28 days age loading

ø 1=	1.9	for	150		
ø 2=	1.7	for	600		
ø =	**1.43**	for	1211	2Ac/u =	1210.91

Ec,eff = 14403.29

deflection = 0.01 mm

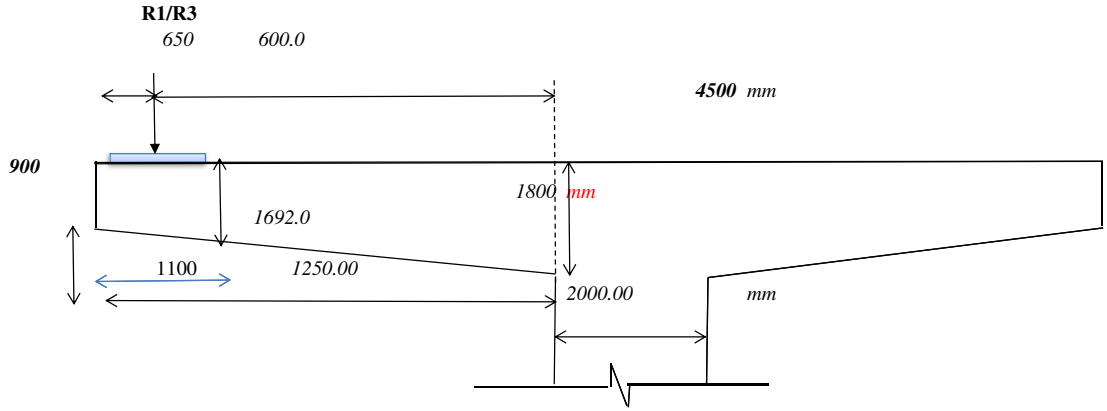
For cantiliver, as per IRC-112:2020, Cl:12.4.1(2)

δ = span / 300 2.00 *mm*

> *0.01* **Hence OK**

Check for Shear ***(As per Cl 10.3 of IRC 112-2020)***

pedestal size= 0.90 x 0.90 x 0.30 mt



Check for Shear at the face of Pedestal @ (R1+R3)

Widh of Pier Cap (B) = 3700 mm

Depth at face of Pedestal (D)= 1692.0 mm

Effective depth at face of Pedestal (d)= *1598.5 mm*

Total Shear force at face of Pedestal = *6214.0 KN*
Moment at face of Pedestal (MT) = *3336.3 KNm*

Effect of Torsion

According to IRC:112-2020, Cl:10.5.2.1 (1), to find the "Design Torsional Shear Force"

Shear stress ($t_{t,i}$)

$$\tau_{t,i} = \frac{T_{Ed}}{2A_k, t_{ef,i}}$$

T_{Ed}	=	2175.5 kN-m
A	=	6260400.0 mm2
U	=	10784.0 mm
$t_{ef,i}$	=	580.53 mm
Ak	=	3467211.3 mm2
Z_i	=	3700.0 mm

$t_{t,i}$ = 0.5 N/mm2

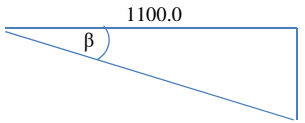
Design torsional shear force ($V_{Ed,i}$)

$V_{Ed,i}$ = $t_{t,i}t_{ef,i}Zi$
= 0.54 x 580.53 x 3700
= 1160801.18 N
= 1160.80 kN

Total shear force (V_{NS}) = 6,214.03 + 1,160.80
= 7374.83 kN

Shear due to depth of Varying section

(From IS 456-2000 Cl:40.1.1) Shear due to Beams of Varying depth = $\frac{Mu \times \tan\beta}{d}$



β = 0.62

$\tan\beta = \frac{792.00}{1100.00} = 0.72$

Mu = 3336.3 KNm

(From IS 456-2000 $\frac{Mu \times \tan\beta}{d}$ = 1502.75 KN

Resultant Shear Force = VEd-Mu x tan β/d = 5872.08 kN

Check for $V_{Rd.c}$ *(As per Cl 10.3.2 of IRC 112-2020)*

The design shear resistance $V_{Rd.c} \geq V_{Ed.}$

The design shear resistance of the member without shear reinforcement $V_{Rd.c}$ is given by:

$$V_{Rd.c} = \left[0.12K(80\rho_1 . f_{ck})^{0.33} + 0.15\sigma_{cp} \right] b_w.d$$

Subject to a minimum of $v_{Rd.c} = (v_{min} + 0.15\sigma_{cp})\, b_w.d$ **Eq. 10.1**

$K = 1 + \sqrt{\frac{200}{d}} \leq 2.0$ **where d is depth in millimeters.** **Eq. 10.2**

and $v_{min} = 0.031K^{3/2} f_{ck}^{1/2}$, **Eq. 10.3**

σ_{cp} is limited to $0.2 f_{cd}$ (MPa) where $\sigma_{cp} = N_{Ed} / A_c < 0.2 f_{cd}$ **(MPa)**

$\rho_1 = \frac{A_{sl}}{b_w.d} \leq 0.02$ **(Fig.10.5)**

ρ1	=	0.001	
	=	0.001	
K	**=**	1.35	
N_{Ed}	**=**	0.00	KN
Ac	**=**	6260400.0	mm^2
σ_p	**=**	0.00	N/mm^2
$V_{Rd.c}$	**=**	**2934.11**	**kN**
V_{Ed}	=	5872.08	kN
$V_{Rd.c}$	<	V_{Ed}	

Hence Shear Reinforcement Required

As per A4.6.1, eq A4.5, IRC:112-2020,

V_{NS} = (ASW / S) * z * fywd * cot θ

f_{ywd} = 434.78 N/mm^2

Spacing (S) required = (ASW * z * fywd * cot θ / VNS

= 171 mm

Assuming

Hence proved **8 L** **Y - 16** **@ 130** **mm c/c**

Check for crushing of concrete (As per Cl 10.3.3.2 of IRC 112-2020)

At the face of Pedestal @ (R1+R3)

VRD.max = **αcw * bw * z * vi * fcd / (cotθ + tanθ)**

VRD.max = Crushing of compressive force for concrete

αcw =	1	
bw =	3700	mm
vi =	0.50	v=0.6*(1-fck/310)
fcd =	22.30	N/mm2

Z = 1438.650 mm

VRD.max = 29867.2 > 7117.0 kN

Hence Safe

Combined Check for Torsion and Shear (As per Cl 10.5.2 (4) of IRC 112-2020)

At the face of Pedestal @ (R1 +R3)

$TRd.max = 2v * \alpha cw * fcd * Ak * tef.i * \sin\theta * \cos\theta$

TEd = 2175.54 kN-m
TRd.max =
VEd = 6214.03 kN
VRd.max = 29867.21 kN
v = 0.50
TRd.max =

Ak = 3467211.26 mm2 $(b-t_{ef,i}) \times (D-t_{ef,i})$
A= 6260400.00 mm2
u = 10784.00 mm
tef.i = 580.53 mm
TRd.max = 22580.79 kN-m

(TEd / TRd.max) + (VEd / VRd.max) ≤ 1.0 = 0.304

Hence Safe

Torsional Reinforcement (As per Cl 10.5.2 (5) of IRC 112-2020)

At the face of Pedestal @ (R1+R3)

Ak = 3.47 m2
T_{ed} = 2175.54 kN-m
u_k = 8.46 m
fyd = 478.26 N/mm2

$$\Sigma asl = \frac{T_{Ed} * \cot\theta * uk}{2A_k * fyd}$$

$$\Sigma asl = \frac{2{,}175.54 \times \cot(1) \times 8.46}{2 \times 3.47 \times 47{,}82{,}60{,}869.57}$$

0.0056 m2
5550.84 mm2

Required Longitudinal reinforcement will be distributed on 4 faces
Ast per face = 1387.710315
Hence Provide **Y - 20** **9 Nos**

Summary of Pier Cap Design:

1	*pier cap size =*	***4500 x***	***3700 x***	**1800 /**	**900.0**	***mm***		
2	*Grade of concrete =*		***M - 50***					
3	*Grade of steel =*		***Fe - 550***					
4	Tension Reinforcement in Transverse Direction =		**25**	**18 Nos**	**in One layer**	**or**	**9 Nos**	**in Two layers**
4a	Compression Reinforcement in Transverse Direction =		**Y 16**	**18 Nos**				
5	*Vertical stirrups =*		**8 L**	***- Y 16***	**130 c/c**	**in Trasverse direction**		
6	*Torsional Reinforcement*		**Y 20**	**9 Nos**	**on either side of Pier beam in Transverse Direction**			

3) DESIGN OF PIER

Forces at Base of the pier and Foundation bottom:

i) Vehicle on one span for 45.00 m LEFT Span) (Without impact Factor)

Sl No	Vehicle case	R1(kN)	R2(kN)	R1(kN) Lane Reduction	R2(kN) Lane Reduction	Total reaction (kN)(Lane Reduction)	eL (mt)	ML (kNm)	eT (mt)	MT (kNm)
1	2CA	673.33	387.82	673.33	387.82	1061.14	1.25	1326.43	0.43	456.82
2	70R	745.16	115.76	670.65	104.18	774.83	1.25	968.54	1.17	906.34

ii) Vehicle on one span for 45.00 m RIGHT Span) (Without impact Factor)

Sl No	Vehicle case	R6(kN)	R7(kN)	R6(kN) Lane Reduction	R7(kN) Lane Reduction	Total reaction (kN)(Lane Reduction)	eL (mt)	ML (kNm)	eT (mt)	MT (kNm)
1	2CA	672.78	387.36	672.78	387.36	1060.14	1.25	1325.17	0.43	456.67
2	70R	744.52	116.40	670.07	104.76	774.83	1.25	968.54	1.17	904.49

iii) Vehicle on Both Spans(without imact factor):

Sl No	Vehicle case	R1(kN)	R2(kN)	R3(kN)	R4(kN)	R1(kN) Lane Reduction	R2(kN) Lane Reduction	R3(kN) Lane Reduction	R4(kN) Lane Reduction	Total reaction (kN)(Lane Reduction)
1	2CA	178.24	69.75	183.63	71.86	175.30	68.60	180.60	70.68	495.18
2	70R	414.05	66.89	405.88	65.57	407.22	65.79	399.19	64.49	936.68

eL (mt)	ML (kNm)	eT (mt)	MT (kNm)
1.3	9.225	0.700	346.61
1.3	11.677	1.155	1081.81

iv A)Braking force from 45.00 m LEFT Span

Sl No	Vehicle case	1st,2nd and 3rdLANE in kN	3rd LANE in kN	1st & 2nd LANE(20%) in kN	3rd LANE(10%) in kN	Total HL in kN	HL per Trestle (kN)	L.A For Pier Base
1	2CA	1108.00	1108.00	221.60	110.80	332.40	166.20	9.25
2	70R	1000.00	0.00	200.00	0.00	200.00	100.00	9.25

ML @ pier base	LA for Found^{n}	ML @ Found^{n}	Add Axial load(kN)
1536.52	11.15	1852.30	36.153
924.50	11.15	1114.50	21.753

iv B)Braking force from 45.00 m RIGHT Span

Sl No	Vehicle case	1st,2nd and 3rdLANE in kN	3rd LANE in kN	1st & 2nd LANE(20%) in kN	3rd LANE(10%) in kN	Total HL in kN	HL per Trestle (kN)	L.A For Pier Base
1	2CA	1108.00	1108.00	221.60	110.80	332.40	166.20	9.25
2	70R	1000.00	0.00	200.00	0.00	200.00	100.00	9.25

ML @ pier base	LA for Foundn Bottom	ML @ Foundn base	Add Axial load(kN)
1536.52	11.15	1852.30	36.153
924.50	11.15	1114.50	21.753

iv A)Longitudinal Effect:(Frictional force) (From 30m LEFT span)

(one Span loaded case(Without impact Factor): Horizontal Force @ Bearing Levl (Single Span)

Sl No	Vehicle case	Fh	μ	Rg / one side of span	Rq (one side of span)	μ (Rg + Rq) @ Free Bearing
1	2CA	0.00	0.05	3334.68	1043.64	218.92
2	70R	0.00	0.05	3334.68	846.72	209.07
						0.05

L.A For Pier Base	ML @ pier base	LA for Found^{n} Bottom	ML @ Found^{n} base	μ Rg
9.25	2023.88	11.15	2439.82	166.734
9.25	1932.85	11.15	2330.09	166.734

B)Longitudinal Effect:(Frictional force) (From 33.4m LEFT span)

(Both Span loaded case(Without impact Factor): Horizontal Force @ Bearing Levl (Single Span)

Sl No	Vehicle case	Fh	μ	Rg / one side of span	Rq (one side of span)	μ (Rg + Rq) @ Free Bearing	L.A For Pier Base	ML @ pier base	LA for Found^{n} Bottom	ML @ Found^{n} base
1	2CA	0.00	0.05	3334.68	247.99	179.13	9.25	1656.09	11.15	1996.44
2	70R	0.00	0.05	3334.68	432.85	188.38	9.25	1741.54	11.15	2099.46

B)Longitudinal Effect:(Frictional force) (From 33.4m RIGHT span)

(One Span loaded case(Without impact Factor): Horizontal Force @ Bearing Levl

Sl No	Vehicle case	Fh	μ	Rg / one side of span	Rq (one side of span)	Fh+μ (Rg + Rq) @ Fixed Bearing
1	2CA	332.40	0.05	3334.68	1042.65	551.27
2	70R	200.00	0.05	3334.68	846.72	409.07

L.A For Pier Base	ML @ pier base	LA for Found^{n} Bottom	ML @ Found^{n} base	μ Rg
9.25	5096.46	11.15	6143.87	166.734
9.25	3781.85	11.15	4559.09	166.734

C)Longitudinal Effect:(Frictional force) (From 30m RIGHT span)

(Both Span loaded case(Without impact Factor): Horizontal Force @ Bearing Levl

Sl No	Vehicle case	Fh	μ	Rg / one side of span	Rq (one side of span)	Fh+μ (Rg + Rq) @ Fixed Bearing	L.A For Pier Base	ML @ pier base	LA for Found^{n} Bottom	ML @ Found^{n} base
2	2CA	332.40	0.05	3334.68	255.49	511.91	9.25	4732.60	11.15	5705.22
3	70R	200.00	0.05	3334.68	424.30	387.95	9.25	3586.59	11.15	4323.69

v) SELF WEIGHT OF PIER AND PIER SUBSTRUCTURE:

Pedastal size= 0.2430 m^3 Height of pier= 6.995 mt

No of pedastal= 4.0

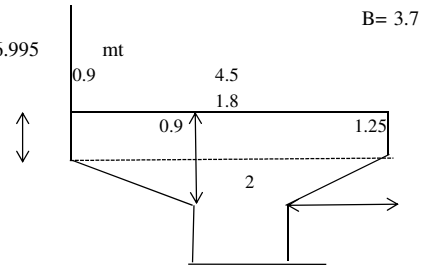
Total sw of pedastal= 24.3 kN

sw of pier beam = 645.2 kN

Area of pier = 5.00 m^2

sw of pier = **874.4** kN

Total sw = ***1543.9*** kN



vi) Wind Force

Wind on Pier Beam :

Width of Pier Cap 3.70 m (b) t/b = 1.22

Height of Pier Cap 1.80 m (h) h/b = 0.49

Length of Pier Cap 4.50 m (t)

Cd 0.844

Force in Transverse direction = Pz X A1 X G X Cd

A1 = 3.70 m X 1.80 m = 6.66 sqm

Ft = 0.203 X 6.66 X 2 X 0.844

2.28 kN

Force in long dirn = 25% of F transverse = 0.6 kN

Wind on Pier :

Width of Pier 2.5 m (b) t/b = 0.80

Height of Pier 6.4950 m (h) h/b = 2.60

Length of Pier 2 m (t)
Cd value 1.29
Force in Transverse direction = Pz X A1 X G X Cd
A1 = 2.50 m X 6.495 m = 16.2375 sqm
Ft = 0.203 X 16.2375 X 2 X 1.285
8.5 kN

Force in long dirn = 25% of F transverse = 2.1 kN

vii) Summary of Wind Load

Wind Force due to DL@ Bearing level	*Lever Arm in mt*	*Transeverse dirction*	*longitudinal dirction*	
Wind force Horizontal due to 45.00 m Left span		45.227	11.31	
Wind force Horizontal due to 45.00 m Right span span		45.227	11.31	
Moment at base of pier due to 45.00 m Left span	9.245	418.13	104.53	
Moment at base of pier due to 45.00 m Right span	9.25	418.13	104.53	
Moment at base of foundation due to 45.00 m Left span	11.15	504.06	126.01	
Moment at base of foundation due to 45.00 m Right span	11.15	504.06	126.01	
Total Horizontal Wind force		90.5	22.6	kN
Total Moment at base of pier		836.3	209.1	kNm
Total Moment at base of foundn	11.145	1008.1	252.0	kNm
Wind on pier Cap		***FT***	***FL***	
Wind force Horizontal		2.3	0.6	kN
Moment at base of pier	7.895	18.0	4.5	kNm
Moment at base of foundn	9.795	22.3	5.6	kNm
Wind on pier		***FT***	***FL***	
Wind force Horizontal	m	8.5	2.1	kN
Moment at base of pier	3.748	31.7	7.9	kNm
Moment at base of foundn	5.648	47.8	11.9	kNm
Total wind load on DL only		***FT***	***FL***	
Wind force Horizontal		101.2	25.3	kN
Moment at base of pier		885.9	221.5	kNm
Moment at base of foundn		1078.2	269.5	kNm
Wind due to LL at bearing level		***FT***	***FL***	
Wind force Horizontal due to 45.00 m span		21.9	5.47	
Wind force Horizontal due to 45.00 m span		21.9	5.47	
Moment at base of pier due to 45.00 m span	9.245	202.30	50.58	
Moment at base of pier due to 45.00 m span	9.245	202.30	50.58	
Moment at base of foundation due to 45.00 m span	11.145	243.88	60.97	
Moment at base of foundation due to 45.00 m span	11.145	243.88	60.97	
Total Horizontal Wind force		43.8	10.9	
Total Moment at base of pier		404.6	101.2	kNm
Total Moment at base of foundn		487.8	121.9	kNm

Wind force Vertical in kN	*(From Both spans)*		345.200	kN

ix) Seismic Analysis of Pier Sub Structure:

The seismic analysis is carried out as per the IRC: 6 – 2017 (Cl:219).

Feq = Ah x (Dead Load + Appropriate live load)

Where,

Ah = Horizontal seismic co – efficient

AR = Z.I / 2.R x Sa / g

Z = zone factor = 0.1 ***(Zone – II)*** (Table-16 of IRC 6-2017)

R = 2.5 (Table-20 of IRC 6-2017)

I = 1.2 (Table-19 of IRC 6-2017)

Dead Load Rxn =			*6669.36*	***kN***
VLL Rxn =	*20%*	*936.68*	*187.34*	***kN***
Total =			6856.6968	***kN***

As Per IRC:6- 2017 *(Annexure-D)*

$T=2\sqrt{W/(1000F)}$

$WL^3/3EI$ = 1.0

W= 259.537 ***kN***

T= 0.325 ***Sec***

Sa /g = 3.076

T = 0.33 *sec*

Sa /g = 2.500

Ah = *0.1*1.2*2.50/(2*2.5)* ***0.060***

l = Height of pier = 9245 *mm*

Ecm = 35000.0 N/mm^2

$I_{gr} = \frac{b \times d3}{12}$

Igr = 2604166666667 mm^4

I_{eff} = 1.95313E+12 mm^4 *(0.75 x Igr)*

Ecm = 35000 MPa (as per IRC-112, table-6.5)

Ec,eff = 35000.00 MPa 2Ac/u = 1111.11

i) Longitudinal direction:(Dead Loads)

Sl No	Component	Total vertical Load in kN	**Total Seismic load (Long-HL)**	
1	DL	6669.36	**400.16**	
2	Pier cap	645.19	38.71	
3	pedastals	24.30	1.46	
4	Pier	874.38	52.46	

ii) Transeverse direction:(Dead Loads)

Sl No	Component	Total vertical Load in kN	**Seismic load (Trans-HT)**	
1	DL	6669.36	**400.16**	
2	Pier cap	645.19	**38.71**	
3	pedastals	24.30	**1.46**	
4	Pier	874.38	**52.46**	

iii) Vertical direction:(Dead Loads)

Sl No	Component	Total vertical Load in kN	**Seismic load (Vertical-Vs)**	
1	DL	6669.36	**266.77**	
2	Pier cap	645.19	**25.81**	
3	pedastals	24.30	**0.97**	
4	Pier	874.38	**34.98**	

Seismic in Longitudinal Direction due to 45.00 m span						**Total ML @ pier base**	**Total ML @ Footing bottom**
Component	**HL**	LA w.r.to pier base	**ML @ pier base**	LA w.r.to pier base	**ML @ Footing bottom x 1.35**		
DL	400.16	10.4605	4185.89	12.3605	6677.37	**4185.89**	**6677.4**
Pier cap	38.71	7.8950	305.63	9.7950	511.89	**305.63**	**511.9**
pedastals	1.46	8.9450	13.04	10.8450	21.35	**13.04**	**21.3**
Pier	52.46	3.4975	183.49	5.3975	382.27	**183.49**	**382.3**

Seismic Transverse Direction due to 45.00 m span						**Total MT @ pier base**	**Total MT @ Footing bottom**
Component	**HT**	LA w.r.to pier base	**MT @ pier base**	LA w.r.to pier base	**MT @ Footing bottom x 1.35**		
DL	400.16	10.461	4185.89	12.36	6677.37	**4185.89**	**6677.4**
Pier cap	38.71	7.895	305.63	9.80	511.89	**305.63**	**511.9**
pedastals	1.46	8.945	13.04	10.85	21.35	**13.04**	**21.3**
Pier	52.46	3.498	183.49	5.40	382.27	**183.49**	**382.3**

Note: ***1.35*** For design of foundation, the seismic loads should be taken as 1.35 times the forces transmitted to it by concrete substructure.(219.8 of IRC 6-2017)

iv) Vehicle on one span(Without impact Factor) Seismic case: for 45.00 m LEFT Span

Sl No	Vehicle case	**Seismic load (Vertical-V_s)**	**Seismic load (Long-HL)**	**Seismic load (Trans-HT)**	lever arm w.r t.pier base	**MT (kNm) pier base due to seismic**	**MT due to VLL Eccentricity**
1	2CA	**443.200**	**0.000**	**26.592**	9.245	**245.84**	**91.36**
2	70R	**160.000**	**0.000**	**9.600**	9.245	**88.75**	**181.27**

LA w.r.to Found^{n} Bottom	**MT (kNm) Footing bottom (due to seismic) x 1.35**	**Total MT @ Footing Base**	**ML due toVLL Eccentricity (kN-m)**
11.145	**400.10**	**491.46**	**265.29**
11.145	**144.44**	**325.71**	**193.71**

v) Vehicle on one span(Without impact Factor) Seismic case: for 45.00 m RIGHT Span

Sl No	Vehicle case	**Seismic load (Vertical-V_s)**	**Seismic load (Long-HL)**	**Seismic load (Trans-HT)**	lever arm w.r t.pier base	**MT (kNm) pier base due to seismic**	**MT due to VLL Eccentricity**
1	2CA	**443.20**	**0.000**	**26.592**	9.245	**245.84**	**91.33**
2	70R	**160.00**	**0.000**	**9.600**	9.245	**88.75**	**180.90**

LA w.r.to Found^{n} Bottom	**MT (kNm) Footing bottom due to seismic x 1.35**	**Total MT @ Footing Base**	**ML due to VLL Eccentricity (kN-m)**
11.145	**400.10**	**491.43**	**265.03**
11.145	**144.44**	**325.34**	**193.71**

vi) Vehicle on Both Span (without imact factor):

Sl No	**Vehicle case**	**Seismic load (Vertical-V_s)**	**Seismic load (Long-HL)**	**Seismic load (Trans-HT)**	L Arm W.r t.pier base	**MT (kNm) pier base due to seismic**	**MT Due toVLL Eccentricity**
1	2CA	**443.20**	**0.000**	**26.59**	9.245	245.843	**69.32**
2	70R	**160.00**	**0.000**	**9.60**	9.245	88.752	**216.36**

LA W.r t.Found Bottom	**MT (kNm) Footing bottom due to seismic x 1.35**	**ML Due to VLL Eccentricity**
11.145	**400.10**	**1.845**
11.145	**144.44**	**2.335**

vi)Braking force(seismic case): 45.00 m LEFT Span

Sl No	Vehicle case	1st & 2nd LANE in kN	3rd & 4th LANE in kN	HL in 1st & 2nd LANE(20%) in kN	HL in 3rd & 4th LANE(5%) in kN	ML=HL x 0.2 x L.A in kNm	Add Axial load(kN)	**HL per Trestle x 0.20 in kN**	LA at pier base
1	2CA	1108.0	1108.0	221.6	55.4	203.9	4.80	**27.7**	9.25
2	70R	1000.0	0.0	200.0	0.0	147.2	3.46	**20.0**	9.25

LA at footing bottom	**ML @ Pier bottom**	**ML @ Footing bottom**
11.145	**256.09**	**308.72**
11.145	**184.90**	**222.90**

v)Braking force(seismic case): 45.00 m RIGHT Span

Sl No	Vehicle case	1st & 2nd LANE in kN	3rd & 4th LANE in kN	HL in 1st & 2nd LANE(20%) in kN	HL in 3rd & 4th LANE(5%) in kN	ML=HL x 0.2 x L.A in kNm	Add Axial load(kN)	**HL per Trestle x 0.20 in kN**	LA at pier base
1	2CA	1108.0	1108.0	221.6	55.4	203.9	4.80	**27.7**	9.25
2	70R	1000.0	0.0	200.0	0.0	147.2	3.46	**20.0**	9.25

LA at footing bottom	**ML @ Pier bottom**	**ML @ Footing bottom**
11.145	**256.09**	**308.72**
11.145	**184.90**	**222.90**

viA)Frictional (seismic case): 45.00 m LEFT Span

One Span loaded case(Without impact Factor): Horizontal Force @ Bearing Levl (seismic due to VLL is not considered in the direction of traffic (longitudinal direction) as per IRC 6-2017)

Sl No	Vehicle case	Fh x 0.2	**μ**	**Rg / one side of span**	**Rq (one side of span)**	**μ (Rg + Rq) @ Free Bearing**	**μ (Rg)**	L.A For Pier Base
1	2CA	0.0	0.05	3334.7	208.7	**177.2**	**166.73**	9.245
2	70R	0.0	0.05	3334.7	169.3	**175.2**	**166.73**	9.245

ML @ pier base	LA w.r.to Footing Bottom	**ML @ Footing bottom**
1637.9	11.145	**1974.6**
1619.7	11.145	**1952.6**

B)Frictional force(seismic case): 45.00 m Left Span

Both Span loaded case(Without impact Factor): Horizontal Force @ Bearing Levl (seismic due to VLL is not considered in the direction of traffic (longitudinal direction) as per IRC 6-2017)

Sl No	Vehicle case	**Fh x 0.2**	**μ**	**Rg / one side of span**	**Rq (one side of span)**	**μ (Rg + Rq) @ Free Bearing**	**μ (Rg)**	L.A For Pier Base
1	2CA	0.0	0.05	3334.7	248.0	**179.1**	**166.73**	9.245
2	70R	0.0	0.05	3334.7	432.9	**188.4**	**166.73**	9.245

ML @ pier base	LA w.r.to Footing Bottom	**ML @ Footing bottom**
1656.1	11.145	**1996.4**
1741.5	11.145	**2099.5**

C)Frictional force(seismic case): 45.00 m RIGHT Span

One Span loaded case(Without impact Factor): Horizontal Force @ Bearing Levl

Sl No	Vehicle case	Fh x 0.2	**μ**	**Rg / one side of span**	**Rq / one side of span x 0.2**	**Fh+μ (Rg + Rq) @ Fixed Bearing**	**μ (Rg)**	L.A For Pier Base
1	2CA	66.5	0.05	3334.7	208.5	**243.6**	**166.73**	9.245
2	70R	40.0	0.05	3334.7	169.3	**215.2**	**166.73**	9.245

ML @ pier base	LA w.r.to Footing Bottom	**ML @ Footing bottom**
2252.5	11.145	**2715.4**
1989.5	11.145	**2398.4**

D)Frictional force(seismic case): 45.00 m RIGHT Span

Both Span loaded case(Without impact Factor): Horizontal Force @ Bearing Levl

(seismic due to VLL is not considered in the direction of traffic (longitudinal direction) as per IRC 6-2017)

Sl No	Vehicle case	Fh x 0.2	μ	Rg / one side of span	Rq / one side of span x 0.2	Fh+μ (Rg + Rq) @ Fixed Bearing	μ (Rg)	L.A For Pier Base
1	2CA	66.5	0.05	3334.7	51.1	**235.8**	**166.73**	9.245
2	70R	40.0	0.05	3334.7	84.9	**211.0**	**166.73**	9.245

ML @ pier base	LA w.r.to Footing Bottom	ML @ Footing bottom
2179.7	11.145	**2627.6**
1950.5	11.145	**2351.3**

DESIGN OF PIER:

A). PIER LOAD COMBINATIONS

C1 to C4 = *DL+VLL ON ONE SPAN (WITH OUT IF)+(BF + SF)*

C5 to C8 = *DL+VLL ON BOTH SPAN (WITH OUT IF)+(BF + SF)*

C9 to C12 = *DL+VLL ON ONE SPAN (WITH OUT IF)+(BF + SF) +WIND ON SUPER STRUCTURE +WIND ON LIVE LOAD +WIND ON PIER CAP +WIND ON PIER*

C13 to C16 = *DL+VLL ON BOTH SPAN (WITH OUT IF)+(BF + SF)+WIND ON SUPER STRUCTURE +WIND ON LIVE LOAD +WIND ON PIER CAP +WIND ON PIER*

C17 = *DL+SW+WIND ON UNLOADED STURCTURE*

The Pier section is designed as a rectangular section subjected to axial force and bending using SP-16, Design Aids For IS 456. The results are tabulated below:-

Load Factors as per IRC 6-2017 Table B.2

Sl Nos	Loads	VLL is Leading & Wind is accompanying	Wind is Leading & VLL is accompanying
1)	SW =	1.35	1.35
2)	SIDL(W/o WC) =	1.35	1.35
3)	WC =	1.75	1.75
4)	VLL =	1.5	1.15
5)	BRAKING FORCE =	1.5	1.15
6)	WIND =	0.9	1.5
7)	Seismic =	1.5	-

i) Normal and Wind Combination (Factored Loads)

COMB	P in kN	ML in kNm	MT in kNm
C1	13314.14	12290.86	1846.69
C2	12863.07	9760.61	2520.98
C5	12465.19	9941.21	1681.38
C6	13105.85	8332.56	2784.19
C9	13137.21	9684.33	2461.12
C10	12791.38	7911.54	2978.08
C13	12486.35	7882.93	2334.39
C14	12977.52	6649.63	3179.87
C17	11640.10	979.47	332.22

ii) Seismic Combinations (Factored Loads) (As per Cl:219.4 of IRC 6-2017))

C1 = DL+SW of pier + Secondary Force (P+ML +0.3MT) *Seismic in Longitudinal direction*

C2 to C5 = DL+0.2xVLL (with out IF) one span+0.2x(BF , FF) (P+ 0.3ML+ MT)

C6 to C9 = DL+0.2xVLL (with out IF) both span+0.2x(BF,FF) (P+ 0.3ML+ MT) } *Seismic in Transverse direction*

Seismic Forces in Longitudinal Direction

Combinations	P in kN	M_{L1} in kNm	M_{T1} in kNm
C1	12343.10	8971.45	2381.52

Seismic Forces in Transverse Direction

Combinations	P in kN	M_{L2} in kNm	M_{T2} in kNm
C2	13016.54	8198.42	7537.88
C3	12588.30	7696.67	7437.10
C8	13025.17	8122.13	7504.81
C9	12593.49	7836.06	7489.74

PIER LOAD COMBINATIONS (QUASI PERMANENT COMBINATION-Table No B.3 of IRC6-2017)

(PARTIAL SAFETY FACTOR TAKEN AS PER IRC:6,2017, TABLE NO 3.3)

Sl Nos	*Loads*	*VLL is Leading & Wind is accompanying*	*Wind is Leading & VLL is accompanying*
1)	*SW =*	***1.00***	1
2)	*SIDL(W/o WC) =*	***1.00***	1
3)	*WC =*	***1.00***	1
4)	*VLL =*	***0.00***	0
5)	*BRAKING FORCE =*	***0.00***	*0*
6)	*WIND =*	***0.00***	*0*
7)	*Seismic =*	-	-

COMB	P in kN	ML in kNm	MT in kNm	Design BM = $\sqrt{(ML^2+MT^2)}$
C1	8213.22	1541.46	0.00	1541.46

Check for Slenderness Ratio

Size of Pier 2500.000 x 2000.000 *mm*

Clear cover = 40.00 *mm*

Grade of Concrete = M - 50

Grade of Steel = Fe - 550

As per IRC:112-2020, The minimum Ast for Pier is as follows,

1). (Length / radius of gyration) < 12 is "Pedestal Column"

2). (Length / radius of gyration) > 12 is "Other Column"

Radius of Gyration (Rg) = Sqrt(I/A)

Rg = 722

I = 2.60417E+12 mm4

A = 5000000 mm2

Length of pier (Le) =		9679	*Effective lengthas per IRC:112-2020,Table 11.1,pg no 114, = l0*1.3*
Slenderness ratio	L / Rg =	13.41	**HENCE IT IS 'OTHER COLUMN'**

As per 11.2.2 of IRC 112-2020,Effective Length of Pier

(1) For compression members in regular frames, the effective length l_e is determined in the following way:

Braced Members:

$$l_e = 0.5 l_o \sqrt{\left(1+\frac{k_1}{0.45+k_1}\right) x \left(1+\frac{k_2}{0.45+k_2}\right)} \qquad \text{Eq.11.2}$$

Unbraced members:

$$l_e = l_o \; x \max of \left\{ \sqrt{\left(1+10.\frac{k_1.k_2}{k_1+k_2}\right)} \; ; \left(1+\frac{k_1}{1+k_1}\right) x \left(1+\frac{k_2}{1+k_2}\right) \right\} \qquad \text{Eq.11.3}$$

$\sqrt{1+\frac{10.K1.K2}{K1+K2}}$ = 1.22

1+ K1/(1+K1) x (1+ K2/(1+K2) = 1.190

l_o = 7445 mm

l_e = 9.12 m

Limiting Slenderness ratio as per IRC:112-2020, Cl:11.2.1(2),

Limiting Slenderness ratio as per IRC:112-2020, Cl:11.2.1(2)

λ_{lim} = 20.A.B.C / sqrt(n)

n= N_{Ed} / (Ac*fcd)

N_{Ed}=	13314.14	kN			
Ø ef=	φ(∞,to).M_{oEqp}/M_{oEd}				
φ(∞,to) =	*1.756*	*(As per IRC 112-2020,A2.5)*			
Mo_{Eqp} =	*1541.46*	KNm			
Mo_{ED} =	*12290.86*	KNm	Ac=	5000000	mm^2
Ø ef=	0.220		h= 2.Ac /U =	1111.1	mm
A=	0.958		fcd=	22.33	N/mm^2
w=	0.406		n=	0.12	
n=	0.12				
B=	1.346				
C=	0.7				
λ_{lim} =	52.29	>	9.12		

Hence OK

Limiting Slenderness ratio as per IRC:112-2020, Cl:11.2.1(2) (Direct Calculation)

λ_{lim} = 20.A.B.C / sqrt(n)

n= N_{Ed} / (Ac*fcd)

A= 0.70

Second order effects may be ignored if the slenderness ratio λ based on l_e as per Clause 11.2.2 is less than a certain value λ_{lim} as per Eq.11.1.

$$\lambda_{lim} = 20.A.B.C / \sqrt{n} \qquad \text{Eq.11.1}$$

where

A = $1/(1+0.2\phi_{ef})$

ϕ_{ef} *is effective creep ratio.*

$\phi_{ef} = \phi(\infty, t_o).\frac{M_{oEqp}}{M_{oEd}}$

M_{oEqp} *= First order B.M. in quasi-permanent load combination in SLS.*

M_{oEd} *= First order B.M. in design load combination in U.L.S.*

B = $\sqrt{1+2\omega}$

C = $1.7 - r_m$

ω = $A_s f_{yd} / (A_c f_{cd})$ *mechanical reinforcement ratio.*

A_s = *is the total area of longitudinal reinforcement.*

n = $N_{Ed} / (A_c f_{cd})$ *relative normal force*

r_m = M_{01} / M_{02} *moment ratio*

M_{01}, M_{02} *are the first order end moments at two ends of member as calculated from the analysis of structure, where* $|M_{02}| \geq |M_{01}|$.

If the end moments M_{01} & M_{02} *give tension on the same side,* r_m *should be taken positive (i.e. C ≤ 1.7), otherwise negative (i.e. C >1.7).*

In the following cases, r_m *should be taken as 1.0 (i.e. C = 0.7):*

- For unbraced members in general.
- For braced members in which the first order moments arise

predominantly from imperfections or transverse loading.

B=	1.10		
C=	0.70		
Ac=	5000000 mm2		
fcd=	22.33 N/mm2	**(α*fck/λ_m)**	*cl:6.4.2.8(1)*
N_{Ed}=	13314.14 kN		
n=	0.12		
λ_{lim} =	31.22		
>	9.12	**Hence OK**	

Design of Vertical Reinforcement

Check for design of Bi-axial Column (For Rectangular column)

As per 8.3.2(4)of IRC 112-2020, Pg no 75
For Rectangular column,

$$\left(\frac{M_{Edx}}{M_{Rdx}}\right)^{a} + \left(\frac{M_{Edy}}{M_{Rdy}}\right)^{a} \le 1 \qquad \text{Eq. 8.3}$$

where
M_{Edx}, M_{Edy} Design moment around the respective axis, including nominal 2nd order moments.
M_{Rdx}, M_{Rdy} Moment resistance in the respective direction
Exponent as follows;
- for circular and elliptical cross-sections: $\alpha = 2$
- for rectangular cross-sections:

N_{Ed}/N_{Rd}	0.1	0.7	1.0
α =	1.0	1.5	2.0

With linear interpolation for intermediate values.
N_{Ed}= design value of axial force.
$N_{Rd} = A_c f_{cd} + A_s f_{yd}$ design axial resistance of section.

Size of Pier = 2000 x 2500.00

Combinations	**Normal Combination**			**Seismic Longitudinal**	**Seismic Transverse**	As per SP-16, Cl 3.3, Pg no 104,
Grade of Concrete	50			50.00	50	N/mm2
Grade of Steel	550			550.00	550	N/mm2
b	2000.00			2000.00	2000.00	
d	2500.00			2500.00	2500.00	
Pu	13314.14	13314.14	12977.52	12343.10	13016.54	kN
Mux	12290.86	12290.86	6649.63	8971.45	8198.42	kN-m
Muy	1846.69	1846.69	3179.87	2381.52	7537.88	kN-m
d'/D	0.030			0.030	0.030	
α	1.01	1.00	1.00	1.00	1.00	(for circular & eliptical as per
Assume Pt	**0.500**	**0.500**	**0.500**	**0.500**	**0.500**	IRC:112-2020, Cl:8.3.2, Pg no 75)
Ast Required (As pro)	25000.0	25000.0	25000.0	25000.0	25000.0	
p / fck	0.0100	0.0100	0.0100	0.0100	0.0100	
Pu/(fck*b*D)	0.053	0.053	0.052	0.049	0.052	
Mu/(fck*b*D*D)	0.035	0.035	0.035	0.035	0.035	(from Chart 47, using SP-16)
Mu/(fck*D*b*b)	0.035	0.035	0.035	0.035	0.035	(from Chart 47, using SP-16)
Mu (Longer Direction)	21875	21875.0	21875.0	21875.0	21875.0	kN-m
Mu (shorter Direction)	17500	17500.0	17500.0	17500.0	17500.0	kN-m (Resisting moment for provided steel)
Interaction ratio	$\left(\frac{M_{Edx}}{M_{Rdx}}\right)^{a} + \left(\frac{M_{Edy}}{M_{Rdy}}\right)^{a} \le 1$			(8,971.45/21,875.00) ^1.00 + (2,381.52/17,500.00) ^1.00	(8,198.42/21,875.00) ^1.00 + (7,537.88/17,500.00) ^1.00	
				0.41 + 0.14	0.37 + 0.43	
	0.66	**0.67**	**0.48**	= 0.55	= 0.80	< 1.00
	Hence O.K			**Hence O.K**	**Hence O.K**	

Total Area of steel required	25000	25000	25000	25000	25000	mm^2
Ast Provided =	Y25	-	56 Nos	Y25 - 56 Nos	Y25 - 56 Nos	
	27488.9			27488.9	27488.9	
Total Area of Steel provided	27488.94			27488.94 mm^2	27488.94 mm^2	
Provided pt	0.563			0.563	0.563	
	Hence O.K			Hence O.K	Hence O.K	

Pier is checked for Max P, Max ML and Max MT cases under normal combination

As per IRC 112-2020 Cl:16

Ast.Min =	3062.252 mm^2	$0.1N_{Ed}/f_{yd}$
Ast.Min =	10000 mm^2	0.002 Ac
Ast.Min =	12000 mm^2	0.0024 Ac
Ast.Max =	200000 mm^2	0.004Ac

Lateral ties

As per IRC:112-2020, Cl:16.2.3,

Dia of lateral tie is max of below,

i). 8 mm

ii). One quarter of max dia of longitudinal bars 8 mm

Hence provide 8 mm

Spacing of lateral tie is min of below,

i). 12 times min dia of longitudinal bars 384.00 mm

ii). The least dimension of the column 1767.77 mm

iii). 200 mm 200.00 mm

Hence provide 150

Hence provide **Y - 8 @** **150 c/c**

Summary

1 *Pier Size =* *(Circular Pier* 2500 mm Dia)

2 *Grade of concrete =* *M - 50*

3 *Grade of steel =* *Fe - 550*

4 *Main Longitudinal reinforcement=* **Y- 25 of 56 Nos**

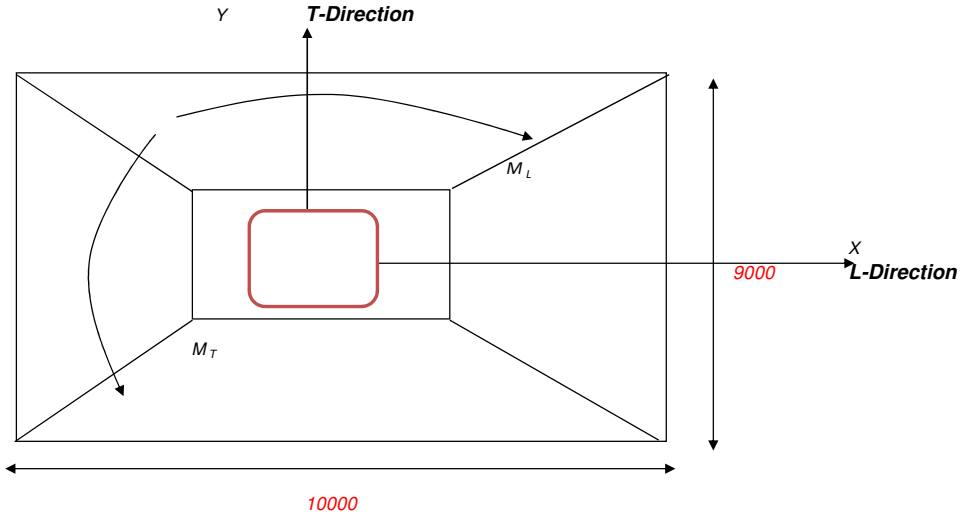
5 *Lateral Ties =* ***Y - 8 @ 150 c/c*** **above the confinement reinforcemnt.**

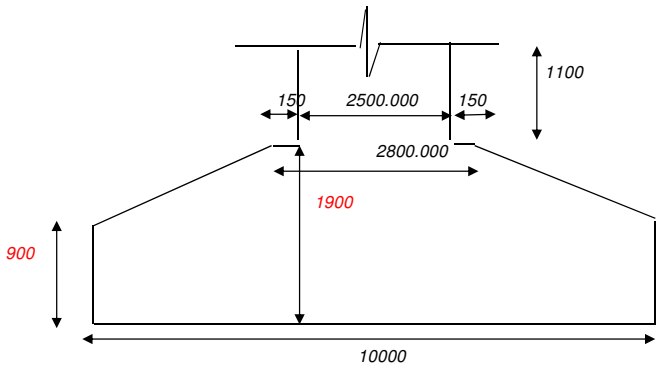
4) DESIGN OF FOUNDATION

AS PER IRC6:2017, TABLE 3.4, PAGE NO 71, THE LOAD FACTORS IS AS UNDER

Sl Nos	Loads	For Footing			For SBC		
		VLL is Leading & Wind is accompanying	Wind is Leading & VLL is accompanying	Seismic is Leading & VLL is accompanying	VLL is Leading & Wind is accompanying	Wind is Leading & VLL is accompanying	Seismic is Leading & VLL is accompanying
1)	SW =	***1.35***	1.35	1.35	***1.00***	1	1

2)	SIDL(W/o WC) =	**1.35**	1.35	1.35	**1.00**	1	1
3)	WC =	**1.75**	1.75	1.75	**1.00**	1	1
4)	VLL =	**1.50**	1.15	0.75	**1.00**	1	0.2
5)	BRAKING FORCE =	**1.50**	1.15	0.75	**1.00**	1	0.2
6)	WIND =	**0.90**	1.5	-	**1.00**	1	-
7)	Seismic =	-	-	1.5	-	-	1





SELF WEIGHT OF FOUNDATION:

Length of Footing (Longitudinal) =	*10000.0*	*mm*
Width of Footing (Transverse) =	*9000.0*	*mm*
Thickness of Footing =	*1900.0*	*mm*
Height of soil =	*1100.0*	*mm*
Sw of the foundation =	*3029.3*	*kN*
Rectangular portion =	*81.0*	m^3
Traphezoidal portion =H/3 ((A1+A2+Sqrt(A1xA2)) =	*40.2*	m^3
Total volume =	*121.2*	m^3
Wt of soil =		*kN*
Rectangular portion =	*270.0*	m^3
Total volume =	148.8	m^3
Wt of soil =	2976.567445	*kN*
SBC =	450.00	*kN/m2*

Load Factors as per IRC 6-2017 Table B.3

Sl Nos	Loads	VLL is Leading & Wind is accompanying	Wind is Leading & VLL is accompanying
1	SW =	1	1
2	SIDL(W/o WC) =	1	1
3	WC =	1	1
4	VLL =	1	0.75
5	BRAKING FORCE =	1	0.75
6	WIND =	0.6	1
7	Seismic =	1	-

Load Combinations

C1 to C4 = *DL+VLL ON ONE SPAN (WITH OUT IF)+(BF + FF)*

C5 to C8 = *DL+VLL ON BOTH SPAN (WITH OUT IF)+(BF + FF)*

C9 to C12 = *DL+VLL ON ONE SPAN (WITH OUT IF)+(BF + SF) +WIND ON SUPER STRUCTURE +WIND ON LIVE LOAD +WIND ON PIER CAP +WIND ON PIER*

C13 to C16 = *DL+VLL ON BOTH SPAN (WITH OUT IF)+(BF + SF)+WIND ON SUPER STRUCTURE +WIND ON LIVE LOAD +WIND ON PIER CAP +WIND ON PIER*

C17 = *DL+SW+WIND ON UNLOADED STURCTURE*

i) Normal and Wind Combination (Unfactored Loads)

Combinations	P in kN	M_L in kNm	M_T in kNm	HL	HT	H=√HL^2+HT^2	*Remarks*
C1	15658.3	9563.4	1396.4	739.7	87.0	744.838	Normal Comb
C2	15357.6	7620.8	1845.9	597.5	87.0	603.843	Normal Comb
C5	15092.4	7945.8	1286.2	712.8	87.0	718.071	Normal Comb
C6	15519.5	6669.7	2021.4	598.1	87.0	604.359	Normal Comb
C9	15522.1	7387.9	1908.5	574.7	145.0	592.735	Wind Comb
C10	15296.5	5930.9	2245.7	468.1	145.0	490.021	Wind Comb
C13	15097.6	6167.7	1825.9	554.5	145.0	573.152	Wind Comb
C14	15417.9	5208.8	2377.3	468.5	145.0	490.394	Wind Comb
C17	15501.0	269.5	269.5	36.2	145.0	149.413	Wind Comb

ii) Seismic Combinations (Unfactored Loads)

C1 = DL+SW of pier + Secondary Force (P+ML +0.3MT) *Seismic in Longitudinal direction*

C2 to C5 = DL+0.2xVLL (with out IF) one span+0.2x(BF , FF) (P+ 0.3ML+ MT)

C6 to C9 = DL+0.2xVLL (with out IF) both span+0.2x(BF,FF) (P+ 0.3ML+ MT) } *Seismic in Transverse direction*

Seismic Forces in Longitudinal Direction

combinations	P in kN	M_L in kNm	M_T in kNm	HL	HT	H=√HL^2+HT^2	Remarks
C1	14797.43	9716.41	2459.13	691.95	437.68	818.752	Seismic
Seismic Forces in Transverse Direction							
C2	15246.38	7116.77	8084.34	609.96	691.86	922.345	Seismic
C3	14960.89	6728.24	7918.58	581.52	674.87	890.849	Seismic
C6	15252.14	6903.80	8062.29	616.33	691.86	926.572	Seismic
C7	14964.36	6730.99	7953.68	601.27	674.87	903.868	Seismic

i) Normal and Wind Combination (Unfactored Loads)

COMB	P in kN	M_L in kNm	M_T in kNm	P1	P2	P3	P4	Remarks
C1	15658.3	9563.4	1396.4	248.1	227.4	99.9	120.6	*Normal Comb*
C2	15357.6	7620.8	1845.9	235.1	207.8	106.2	133.5	*Normal Comb*
C5	15092.4	7945.8	1286.2	230.2	211.1	105.2	124.2	*Normal Comb*
C6	15519.5	6669.7	2021.4	231.9	201.9	113.0	142.9	*Normal Comb*
C9	15522.1	7387.9	1908.5	235.9	207.6	109.1	137.4	*Wind Comb*
C10	15296.5	5930.9	2245.7	226.1	192.9	113.8	147.1	*Wind Comb*
C13	15097.6	6167.7	1825.9	222.4	195.3	113.1	140.2	*Wind Comb*
C14	15417.9	5208.8	2377.3	223.6	188.4	119.0	154.2	*Wind Comb*
C17	15501.0	269.5	269.5	176.0	172.0	168.4	172.4	*Wind Comb*
		For working Combination (Max)		261.07	244.31	154.22	167.19	
		For Working Combination (Min)		170.31	156.40	99.88	120.57	
		For Wind Combination (Max)		295.03	295.03	168.44	172.43	
		For Wind Combination (Min)		176.03	154.33	100.65	100.65	

ii) Seismic Combinations (Unfactored Loads)

COMB	P in kN	ML in kNm	MT in kNm	P1	P2	P3	P4
C1	14797.4	9716.4	2459.1	247.4	211.0	81.4	117.9
C2	15246.4	7116.8	8084.3	276.7	157.0	62.1	181.8
C3	14960.9	6728.2	7918.6	269.7	152.4	62.7	180.0
C6	15252.1	6903.8	8062.3	275.2	155.8	63.7	183.2
C7	14964.4	6731.0	7953.7	270.1	152.2	62.5	180.3

For Seismic Combination (MAX)	276.73	210.98	126.06	238.55
For Seismic Combination (MIN)	235.85	123.36	62.08	117.86

iii) Normal and Wind Combination (Factored Loads)

COMB	P in kN	ML in kNm	MT in kNm	P1	P2	P3	P4	Remarks
C1	21422.05	14345.15	2094.56	349.2	318.1	126.9	157.9	*Normal Comb*
C2	20970.98	11431.14	2768.85	329.7	288.7	136.3	177.3	*Normal Comb*
C5	20573.10	11918.67	1929.25	322.34	293.76	134.84	163.42	*Normal Comb*
C6	21213.76	10004.58	3032.06	324.9	279.9	146.6	191.5	*Normal Comb*
C9	21245.11	10810.61	2874.24	329.42	286.84	142.70	185.28	*Wind Comb*
C10	20899.29	8810.28	3391.19	316.1	265.8	148.4	198.6	*Wind Comb*
C13	20594.26	9454.75	2747.50	312.21	271.50	145.44	186.15	*Wind Comb*
C14	21085.43	7987.28	3592.99	314.1	260.9	154.4	207.6	*Wind Comb*
C17	19983.22	808.63	404.32	230.4	224.4	213.6	219.6	*Wind Comb*
			Max	349.172	318.142	213.650	235.535	
			Min	230.422	208.551	126.873	157.904	

iv) Seismic Combinations (Factored Loads)

COMB	P in kN	ML in kNm	MT in kNm	P1	P2	P3	P4
C1	20237.22	14574.62	4102.02	352.4	291.6	97.3	158.1
C2	21027.07	10675.16	12126.50	394.6	215.0	72.6	252.3
C3	20602.27	10092.36	11877.87	384.2	208.2	73.6	249.6
C6	21088.25	10352.93	12093.44	392.91	213.75	75.71	254.88
C7	20641.25	10092.99	11930.52	385.0	208.3	73.7	250.4
			Max	394.628	291.637	119.104	287.834
			Min	333.391	164.661	72.640	158.079

Design of Footing

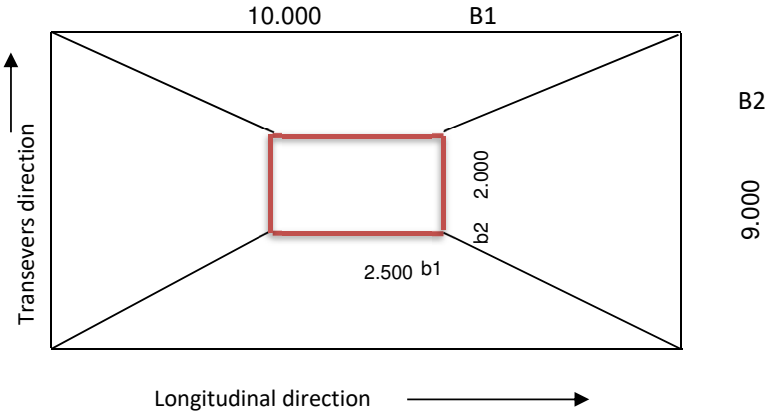
Footing Design is carried out for the Critical combination adopting Limit State Load factors and Partial safety factors for Material, as per IRC:6-2017/IRC:112-2020

Load Combination =

Pu=	21422.048 KNm	This load is the combination of	Normal Comb	for C1
ML=	14345.152 KNm	Longitudinal Design		
MT=	2094.562 KNm			

Pu=	21088.251 KNm	This load is the combination of	Seismic	for C6
ML=	10352.926 KNm	Transverse Design		
MT=	12093.441 KNm			

Footing width in span direction (longitudinal)	(B1)=	10.000 m
Footing width in road way direction (Transverse)	(B2)=	9.000 m
Depth of footing (under column)	(D) =	1.900 m
Depth of footing (at edges)	(D1) =	0.900 m
Dimension of column in span direction	(b1)=	2.500 m
Dimension of column in road way direction	(b2)=	2.000 m
Depth of soil fill at the face of column	=	1.100 m
Depth of soil fill at edge	=	2.100 m



Dia of bars in the span direction	(ds)=	25 mm		
No. of bars	(ns)=	70 No.	in	9.0 m
spacing of the rods	(ss)=	100.000 mm		length
Dia of bars in the road way direction	(dr)=	25 mm		
No. of bars	(nr)=	70 No.	in	10.0 m
spacing of the rods	(sr)=	100.000 mm		length
Edge thickness of footing	(D1)=	0.900 m		
Clear cover to main bars	(d')=	75 mm		
Grade of concrete	(GC)=	M 35		
Grade of steel	(GS)=	550		
Offset of footing top (min 150 mm)	(off)=	0.150 m		

Top dimension of footing (span direction) (B1') = b1+2* offset

= 2.800 m

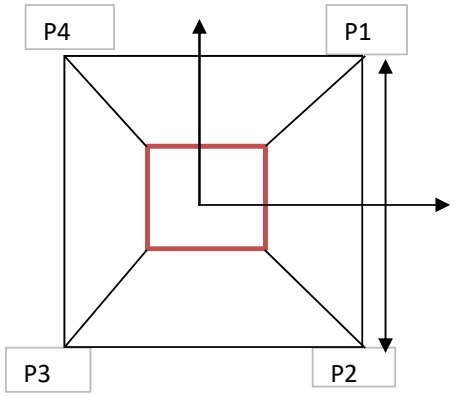
Top dimension of footing (Road way direction) (B2') = b2+2* offset + 2.000 m x 2

= 2.300 m

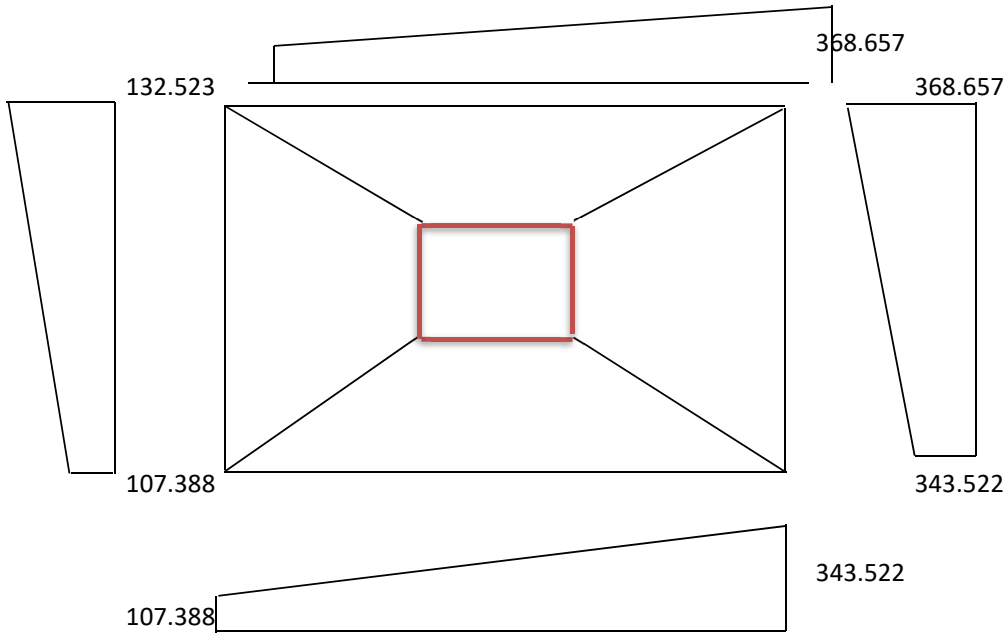
Area of base of footing (A1) = 90 sq.m

Area of top of footing (A2) = 6.44 sq.m

PRESSURES UNDER FOOTING AT ALL CORNERS :



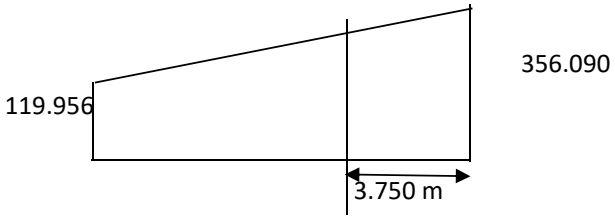
Pmax	(P1) = 368.657	KN/sqm
Pmin	(P3) = 107.388	KN/sqm
	(P2) = 343.522	KN/sqm
	(P4) = 132.523	KN/sqm



Pmax	=	368.657	KN/sqm
Pmin	=	107.388	KN/sqm

A) LONGITUDINAL BENDING MOMENTS :

As per cl.307.2.1 of IRC : 21-2000, the critical section for bending in bases shall be taken at the face of the column



long side (b1)= 2.500 m

distance of critical section from one edge (X) = (B1-b1)/2

= 3.750 m

Pressure at the centre of one edge (P1,2) = (P1 + P2)/2

= 356.090 KN/sqm

Pressure at the centre of other edge (P3,4) = (P3 + P4)/2

= 119.956 KN/sqm

Pressure at critical section (Pc) = P12-((P12-P34)/B1)*X

= 267.540 KN/sqm

Hence Bending moment (BM1) = $Pc*X^2/2 + ((P12-Pc)/2)*X*2/3*X$

= 2296.217 KN/sqm

Hence total Bending moment (BM) = BM1 *B2

= 20665.952 KNm/m

Bending moment due to self weight = 1972.856 KNm/m

Bending moment due to overburden soil weight = 2253.015 KNm/m

Net Bm = 16440.081 KNm/m

Calculation of Reinforcement

Effective width resisting this BM (Ew) = = 3.138 m B2' +(B2- B2')/8

Mu / Ew*d*d = 0.133 * fck 4.66 = Q

dreq = Sqrt (Mu / Q*Ew) limiting depth

= 1060.963075 mm 2.183

dpro = D-d'-0.5d_s 2095.83

= 1812.500 mm

limiting effective depth = 2095.833 mm

min effective depth = 1812.500 mm **Hence safe**

Area of steel required (Ast) = (50*fck/0.87fy)*(1-sqrt(1-(4.5*Mu/(fck*Ew*d2))))

= 23079.88165 mm^2

a) As per IRC:112-2020, Cl:16.5.1.1,

As.min = 0.26*(fctm/fyk)*bt*d not less than 0.0013*bt*d

fctm= 2.8 Mpa from irc:112-2020, table 6.5,

bt= 9000 mm

fyk= Fe - 550 N/mm2

d= 1813 mm

As.min= 21592 mm2

Area of steel required (Ast) = **23080** mm^2

Ast req (Ast) /m run = (23,079.88 / 9)

= 2307.988165 mm^2

no of bars required = **47.02** Nos.

Required Spacing of bars = 212.7 mm

Hence provide = **25** mm Dia **70** Nos

Ast prov = **34361.17** mm^2

Spacing of bars provided = say **100 mm**

Hence provide **25** **100** **c/c**

Hence safe

CHECK FOR SHEAR (LONGITUDINAL DIRECTION) :

As per IRC the critical section for one way shear is considered at a distance equivalent to the eff. depth from the face of the column

Hence the distance of the critical section from the edge (X) = $(B1-b1)/2-d_{prov}$

= 1.938 m

Pressure at the critical section (P_c) = P12-(P12-P34)/B1*X

= 310.339 KN/sqm

Pressure force at the critical section (SF1) = Pc*X + ((P12-Pc)/2)*X

= 645.603 KN

Total pressure force (SF) = SF1 * B2

5810.425229 kN

shear force due to self weight = 516.2295 kN

shear force due to overburden soil weight = 646.7664 kN

Net shear force (V) = 4647.429 KN

Bending moment at the critical section (BM1) = $Pc*X^2/2 + ((P12-Pc)/2)*X*2/3*X$

= 639.740 KN/sqm

Total Bending moment (BM) = BM1 *B2

5757.658163 KNm/m

Net Bending moment (BM) = 5633.327 KNm/m

Depth at critical section for shear (D_c) = D1 + 2(D-D1)/(B1-B')*X

= 1.438 m

Hence Eff depth (d_c) = D_c - d'-0.5d_s = 1350.694444 mm

limiting effective depth = 1458.333333 mm

min effective depth = 1350.694 mm

Net shear force (V) = SF - BM/(d_{prov})*tan β

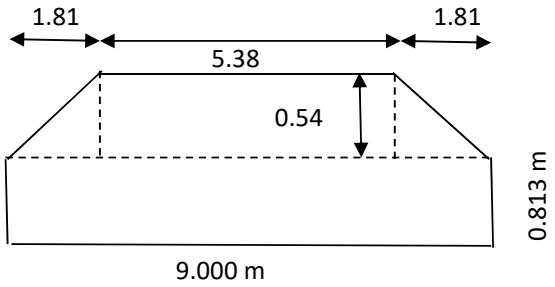
tan β = 2 * (D - D1)/(B1 - B1')

= 0.277778

= 3488.904 KN

Ultimate shear force (Vu) = = 3488.90 kN

= 3488.90 kN



Cross section at critical distance

Width available at critical section (Wc) = B1' + (B1-B1')/(D- D1)*(D-D_C)

= 6.125 m

Effective depth at edge (d_e) = D1 - d' -0.5*d_s

= 812.500 mm

Hence eff. Area resisting shear (A_{eff}) = 9.00 x 0.81 + 0.54 x (1.81+5.38)

= 11180772.569 mm^2

Hence shear stress induced τ_v = Vu / A_{eff}

= 0.312045024 N/mm^2

100 A_s / bd = 0.307

For this value of 100 A_s / bd

Permissible shear stress = 0.400 N/mm^2

Hence safe

Check For Shear as per cl. 10.3.2, IRC:112-2020

V_{Rdc} = $(0.12K(80\rho 1 f_{ck})^{0.33}+0.15\sigma cp)bw.d$

Where,

K= $1+\sqrt{200/d}$

A. Longitudinal Direction

d= 1458.333 mm

K= 1.370

ϑ1 0.0031

bwXd= Effective Area= 11180772.569 mm^2

Neglecting Axial Force, σcp =0

V_{Rdc} = 3740.64 KN

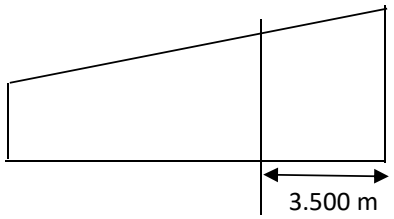
> 3488.90 KN **ok**

Shear Reinforcement Not Reqd

B) TRANSVERSE BENDING MOMENT :

Pmax	(P1) = 392.084	KN/sqm
Pmin	(P3) = 76.544	KN/sqm
	(P2) = 246.963	KN/sqm
	(P4) = 221.665	KN/sqm

As per cl.307.2.1 of IRC : 21-2000, the critical section for bending in bases shall be taken at the face of the column



distance of critical section from one edge (X) = (B2-b3)/2

= 3.500 m

Depth at critical section = 1.945 m

Pressure at the centre of one edge (P41) = (P1 + P4)/2

= 306.875 KN/sqm

Pressure at the centre of other edge (P23) = (P2 + P3)/2

= 161.753 KN/sqm

Pressure at critical section (Pc) = P41-((P41-P23)/B2)*X

= 250.438 KN/sqm

Hence Bending moment (BM1) = $Pc*X^2/2 + ((P12-Pc)/2)*X*2/3*X$

= 1764.383 KN/sqm

Hence total Bending moment (BM) = BM1 *B1

= 17643.830 KNm/m

Bending moment due to self weight = 1911.072917 KNm/m

Bending moment due to overburden soil weight = 2181.891667 KNm/m

Net Bm = 13550.866 KNm/m

Calculation of Reinforcement

Effective width resisting this BM (Ew) = b1' +(B1- b1')/8

= 3.438 m

Mu / Ew*d*d = 0.133 * fck

= 4.655 = Q

dreq = Sqrt (Mu / Q*Ew)

= 920.24 mm

Effective depth provided (d_{prov}) = D-d'-1.5d/2

= 1787.500 mm

limiting effective depth = 1954.166667

min effective depth = 1787.500 mm **Hence safe**

Area of steel required (Ast) = (50*fck/0.87fy)*(1-sqrt(1-(4.5*Mu/(fck*Ew*d2))))

= 18592.57984 mm^2

a) As per IRC:112-2020, Cl:16.5.1.1,

As.min = 0.26*(fctm/fyk)*bt*d not less taha 0.0013*bt*d

fctm= 2.8 Mpa from irc:112-2020, table 6.5,

bt= 10000.000 m mm

fyk= 550 N/mm2

d= 1788 mm

As.min= 23660 mm2

Area of steel required (Ast) = **23660** mm^2

Area of steel required (Ast) /m run = 2628.888889 mm^2

no of bars required **48.20** Nos.

Spacing of bars Required = 186.7229 mm

25 mm Dia **70** Nos

Area of steel provided (Ast prov) = **34361** mm^2

Spacing of bars provided = **143.00** say 100

Area of steel provided (Ast prov) = 34361.17 mm^2

Hence Provide **25** **100** **c/c**

Hence safe

CHECK FOR SHEAR (TRANSVERSE DIRECTION) :

As per IRC the critical section for one way shear is considered at a distance equivalent to the eff. depth from thr face of the column

Hence the distance of the critical section from the edge (X) = $(B2-b3)/2-d_{prov}$

= 1.713 m

Pressure at the critical section (P_c) = P41-(P41-P23)/B2*X

= 279.261 KN/sqm

Pressure force at the critical section (SF1) = Pc*X + ((P41-Pc)/2)*X

= 501.879 KN

Total pressure force (SF) = SF1 * B1

5018.787331 kN

shear force due to self weight = 559.7423 kN

shear force due to overburden soil weight = 631.708 kN

= 3827.337 KN

Bending moment at the critical section (BM1) = $Pc*X^2/2 + ((P41-Pc)/2)*X*2/3*X$

= 436.482 kNm

Total Bending moment (BM) = BM1 *B1

4364.820389 KNm/m

bending moment due to self weight 44.39434 kNm

= 4263.837 KNm/m

Depth at critical section for shear (D_c) = D1 + 2(D-D1)/(B2-B')*X

= 1.411 m

Hence Eff depth (d_c) = D_c - d'-d_r/2

= 1298.69403 mm

Limiting effective depth = 1358.333333 mm

Min effective depth= 1298.694 mm

Net shear force (V) = SF - BM/(d_{prov})*tan β

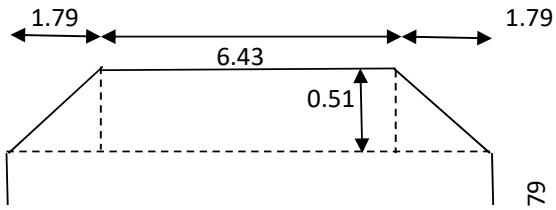
tan β = 2 * (D - D1)/(B2 - B2')

= 0.298507

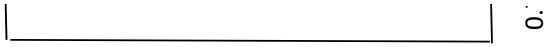
= 2847.285 KN

Width available at critical section (Wc) = B1' + (B1-B1')/(D- D1)*(D-D_C)

= 6.319 m



Effective depth at edge (d_e) = D1 - d' -d_r/2



= 787.500 mm

Hence eff. Area resisting shear (A_{eff}) = 10.00 x 0.79 + 0.51 x (1.79+6.43)

= 12073180.970 mm^2

Hence shear stress induced τ = Vu / A_{eff}

= 0.236 N/mm^2

100 A_s / bd = 0.285

For this value of 100 A_s / bd and M35 grade concrete,

Permissible shear stress = 0.388 N/mm^2

Hence safe

Check For Shear as per cl. 10.3.2, IRC:112-2020

V_{Rdc} = $(0.12K(80\rho1f_{ck})^{0.33}+0.15\sigma cp)bw.d$

Where, K= $1+\sqrt{200/d}$

A. Longitudinal Direction

d= 1298.694 mm

K= 1.392

ρ1 0.0028

bwXd= Effective Area= 12073180.970 mm^2

Neglecting Axial Force, σcp =0

V_{Rdc} = 4001.65 KN

> 2847.29 KN **ok**

Shear Reinforcement Not Reqd

C) PUNCHING SHEAR :

Critical section for punching shear is assumed at distance equal to half the depth from the face of the column

Perimeter = 12100.000 mm

Distance of minimum depth section from one edge (X) = (B2 - b3 - d prov)/2

= 2606.250 mm

Minimum depth available (D_c) = D1 +2(D-D1)/(B1-B')*X
= 1.624 m
Hence minimum eff. Depth available (dc) = D_c - d' -dr/2
= 1511.458 mm
Punching shear stress induced (σ) = P/ (C*dc)
= 0.872 N/mm^2

Allowable punching shear as per IRC:112-2020, Cl:10.4.5, Pg no 104,

v_{min} = 0.30
K = 1.38
ρ_l = 0.02
a = 689.26 mm
v_{Rd} = 2.50 > 1.19 = (v_{min}*2d/a)
= 2.497
= 2.497 N/mm^2 **Hence safe**

Check For Punching Shear,as per cl. 10.4.3, IRC:112-2020

v_{Ed} = $\beta V_{Ed}/u_i d$

$$\beta = 1 + 1.8\sqrt{\left(\frac{e_y}{b_z}\right)^2 + \left(\frac{e_z}{b_y}\right)^2}$$

V_{Ed}= 21422.05
ML = 14345.15
MT = 2094.56
eL = ML/V_{Ed}
eL = 0.67
bL = 5.80
eT = MT/V_{Ed}
eT = 0.10

$$v_{Rd} = 0.12K(80\rho_l f_{ck})^{1/3}\frac{2d}{a} \geq v_{min}\frac{2d}{a}$$

$K = 1 + \sqrt{\frac{200}{d}} \leq 2.0$ where d is depth in millimeters.

$\rho_l = \sqrt{\rho_{ly}\cdot\rho_{lz}} \leq 0.02$

$\rho_{ly}\cdot\rho_{lz}$ relate to the bonded tension steel in y - and z - directions respectively.

$$v_{min} = 0.031K^{3/2} f_{ck}^{1/2}$$

bT = 6.30

β = 1.2

d = 1800.0

a) At D/2 from the face of the column

Perimeter (ui) = 12100.00 mm

$v_{Ed=}$ 1.19 N/mm^2

< Rs. 2.50 **OK**

b) At face of the column

Perimeter (ui) = 9000.00

v_{Ed} = $\beta V_{Ed}/u_i d$

1.60 N/mm^2

$$\nu = 0.6\left[1 - \frac{f_{ck}}{310}\right] \quad f_{ck} \text{ in MPa}$$

v= 0.53

fcd = 0.67*fck/1.5

= 15.63

$$v_{Rd.max} = \frac{1}{2}.\nu.fcd \qquad \textbf{Eq.10.43}$$

$V_{Rd.max}$ = 4.16

> v_{Ed}

> 1.60 **OK**

Stress Check for Provided Steel (Rare Combination)

		Longitudinal Direction	Transverse Direction
Width of Footing (mm) =	b=	9000	10000
Thickness of Footing (mm)	h =	1900	1900

$Ec,eff = Ecm / (1+ \phi)$

Dia of main Bar (mm)	25	25
Effective Depth (deff) mm	1813	1788
Ast pro (mm2)	49087	44179
Max Moment (kN-m)	14745	12350
Es (N/mm^2)	200000	200000
Ecm (N/mm^2)	14101	14101
m = α = Es/Ecm	14.18	14.18
X_U (mm) =	457.8	415
L.A (mm) =	1620.2	1613
Stress in Steel (N/mm2)	185.4	173
Permissible stress in steel	440.0	440
Check for stree in steel	Hence OK	Hence OK
Stress in Concrete (N/mm2)	4.42	3.69
Permissible stress in concrete	17	17
Check for stree in concrete	Hence OK	Hence OK

Ecm = 32000 MPa (as per IRC-112, table-6.5)

As per IRC:112-2020, table-6.9, for RH-80%, & 28 days age loadi

ø 1= 1.9 for 150

ø 2= 1.7 for 600

ø = **1.27** for 1569 2Ac/u = 1568.81

Ec,eff = 14100.53

Crack Width Calculation As per IRC 112-2020

	Longitudinal Direction	Transverse Direction
Dia of main Bar (mm)	25	25
Spacing of Bars (mm)	100	100
Max Moment (kN-m)	16107.11	12117.577
Ast pro As (mm^2)	49087.39	44179
C_{min} (mm)	75	75
a_{cr} (mm)	88.28	88.28
h (mm)	1900.00	1900.00
d (mm)	1812.50	1787.50
Es (N/mm^2)	200000	200000
Ecm (N/mm^2)	14101	14101
m = α = Es/Ecm	14.18	14.18
Xu (mm)	457.82	414.77

σ_{sc} (N/mm^2)	202.52	170.02
k_t =	0.5	0.5

$f_{ct,eff}$ (N/mm^2)		2.8	2.8
$A_{c,eff} = b*h_{c,eff}$ (mm^2)		1968750.00	2812500.00
$h_{c,eff}$ least of	*2.5 (h - d)*	218.8	281.3
	(h - Xu/3)	480.7	495.1
	h / 2	950.0	950.0
$\rho_{P,eff}$ =		0.0249	0.0157
$\varepsilon_{sm} - \varepsilon_{cm}$ =		0.0006	0.0003
		≥ 0.0006	≥ 0.0005
$\varepsilon_{sm} - \varepsilon_{cm}$ =		0.0006	0.0005
IRC 112-2020	k1 =	0.8	0.8
	k2 =	0.5	0.5
Spacing	5(c + F/2) =	312.50	312.50
Case(i)	$S_{r.max}$ $(mm)_=$	425.45	525.56
Case(ii)	$S_{r.max}$ $(mm)_=$	1874.83	1930.79
$S_{r.max}$ (mm) =		425.45	525.56
W_k (mm) =		0.269	0.268
Check for Crack Width		***Hence OK***	***Hence OK***